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Primary School Space Design in the City of Beijing: A Design Demonstration That Promotes the Physical Well-being of Children

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By

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Department of Architecture

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Rochester, NY

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Committee Approval:

"Primary School Space Design in the City of Beijing:
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By Dan Wu

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Abstract:

In recent years, obesity and health problems have increased among children in China because they participate in fewer physical activities than in previous years. The reasons for this change include academic overload, the increased number of students, and the limited amount of open space in cities. It has, therefore, become important to encourage students to engage in more outdoor exercise. Children aged 7 to 12 are considered primary school age in China. They spend most of the day at school, where physical activity opportunities should be provided. Architectural design can help improve the quality of spaces by laying them out efficiently and by making them an appropriate size.

This thesis proposes a redesign of an existing school typical of those found in urban China. The design demonstrates how to increase the opportunities for physical activity by means of architectural intervention. The design focuses on increasing outdoor activity spaces and multi-use spaces, as well as shortening walking routes from the classrooms to the outdoors. The integrated solution will help reduce growing health issues among Chinese children.

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1. Introduction

This chapter introduces of the background of this design thesis including the education systems in China, the location information, and the existing problems. A typical primary school site is selected for analysis to demonstrate how architectural design can improve the situation in Chinese primary schools.

1.1 Education in China

The Chinese education system is challenging and competitive. Chinese primary school includes Grade 1 to 6, with students roughly around aged 7 to 12. Students in Chinese primary schools study and sit longer than in other countries. Figure 1 is a typical class schedule for a Grade 5 student in China. There are around seven classes each day. Students go to school at 7:30 a.m.; classes begin at 8:00 a.m. and finish at around 3:30 p.m., depending on the number of courses, with an hour for lunch and half an hour for a nap or break.[1] Most schools have only 10 minutes of recess between classes, and about 30 minutes for physical activities (assembly activities) every day. Physical education (PE) classes are held two or three days a week. In the 10 minutes of recess time, students generally prefer to stay in the classroom or play in the hallway because the time taken to travel to and from play areas is prohibitive. After school, children still have one to three hours of homework. Some students

[1] Kan Wei, "Copying the Long Chinese School Day Could Have Unintended Consequences," The Conversation, 2014, https://theconversation.com/copying-the-long-chinese-school-day-could-have-unintended-consequences-23398.

need to go to extra-curricular activities, such as music and art.[2] Thus, there is little time for children to play.

五下 English 课程表

日期 / 节次	Monday	Tuesday	Wednesday	Thursday	Saturdar
one	Chinese	English	maths	Chinese	Chinese
two	maths	maths	Chinese	Chinese	maths
three	Chinese	Chinese	Chinese		English
four	science	Chinese	art	music	computer class
five	P.E	music	Chinese	P.E	
six	art	Chinese	Chinese	maths	
seven	Chinese	science	P.E	English	
eight		Chinese			

Figure 1: Weekly schedule of a Grade 5 Chinese primary school student

Figure 2 illustrates the percentage of American school children participating in after-school activities: 73% participate in sports and athletic activities.

In America, elementary school children also have around 30 minutes per day for physical activities at school. Also, they leave school around 2:00 p.m., and their homework takes less than one hour to complete. Sometimes there is no homework. Thus, American children have more free time and motivation for physical activities than Chinese Children.[3]

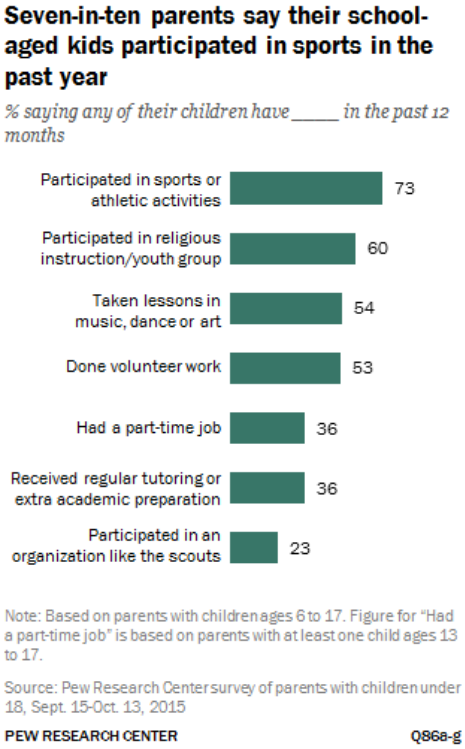
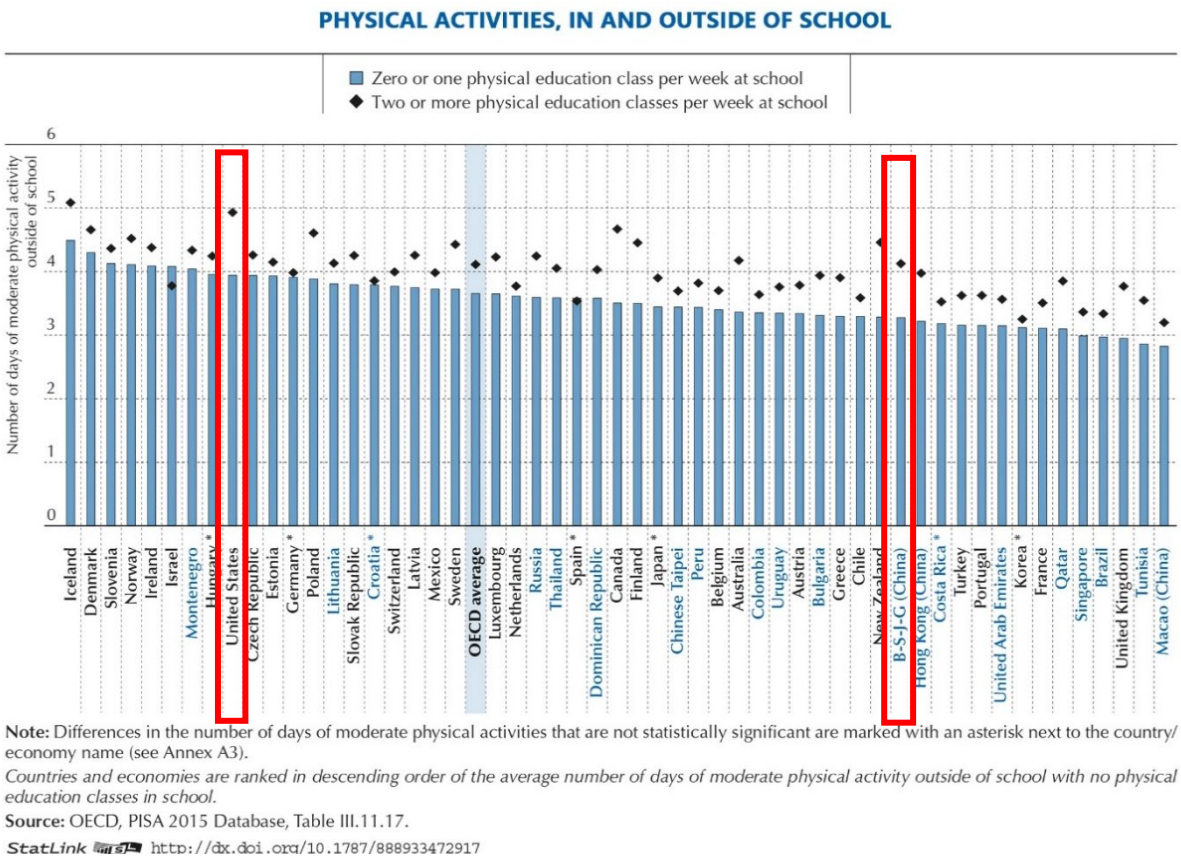


Figure 2: American children's activities

[2] Berlin Fang, "Balancing Extracurricular Activities - Opinion - Chinadaily.Com.Cn," CHINADAILY.COM.CN, August 2012, http://www.chinadaily.com.cn/opinion/2012-08/22/content_15695746.htm.

[3] "Seven-in-Ten Parents Say Their School-Aged Kids Participated in Sports in the Past Year | Pew Research Center," Pew Research Center, December 14, 2015.



Note: Differences in the number of days of moderate physical activities that are not statistically significant are marked with an asterisk next to the country/economy name (see Annex A3).

Countries and economies are ranked in descending order of the average number of days of moderate physical activity outside of school with no physical education classes in school.

Source: OECD, PISA 2015 Database, Table III.11.17.

StatLink http://dx.doi.org/10.1787/888933472917

Figure 3: Total activity time

The Organization for Economic Co-operation and Development (OECD), conducts the Programme for International Student Assessment (PISA) for students around the world every three years. Figure 3, the table of physical activities in and outside of school,[4] reveals that students in China spend less time on physical activity than American Children. The number of days of physical activity for students in China is below both the United States (US) and the overall average.

Urban Chinese elementary schools seldom have playgrounds and do not allow children access to them after school hours. American schools have a stronger physical activity

[4] "PISA 2015 Results (Volume III) - Students' Well-Being - En - OECD," OECD, Paris, April 2017, http://www.oecd.org/education/pisa-2015-results-volume-iii-9789264273856-en.htm.

infrastructure with large, open areas, and children have many choices of where to play. In comparison, in Chinese cities, the educational infrastructure allows for less physical activity time and affords fewer opportunities to engage in physical activities.

1.2 What Do They Need?

Education systems are difficult to improve in a few years and are regulated by the Ministry of Education, but architects can change school environments within a few months. Primary school campuses in China should have more outdoor spaces and be conveniently accessible. Multiple outdoor spaces and facilities can provide students with a comfortable workout environment that motivates them to step outside.

In addition, recess time is limited, so the time spent to go outside should be minimized. Both site and building designs are essential for schools. To improve the physical activity situation in a primary school, the design should maximize outdoor spaces and reduce the walking distance between classrooms and outdoor spaces.

1.3 Location

Beijing is a developing and dense city. It is the model for other cities in China. New school designs could be guides to apply to other schools in Beijing and other dense cities to promote the physical activities of children.

The development of politics, economics, and education has been more rapid in Beijing than in other cities in China, leading to Beijing attracting more people and growing to become

the second-most populated city in China. Beijing's population density is an estimated 14,300 people per square mile,[5] which is high compared with the US capital, Washington, DC, with a population density of 11,535 people per square mile.[6]

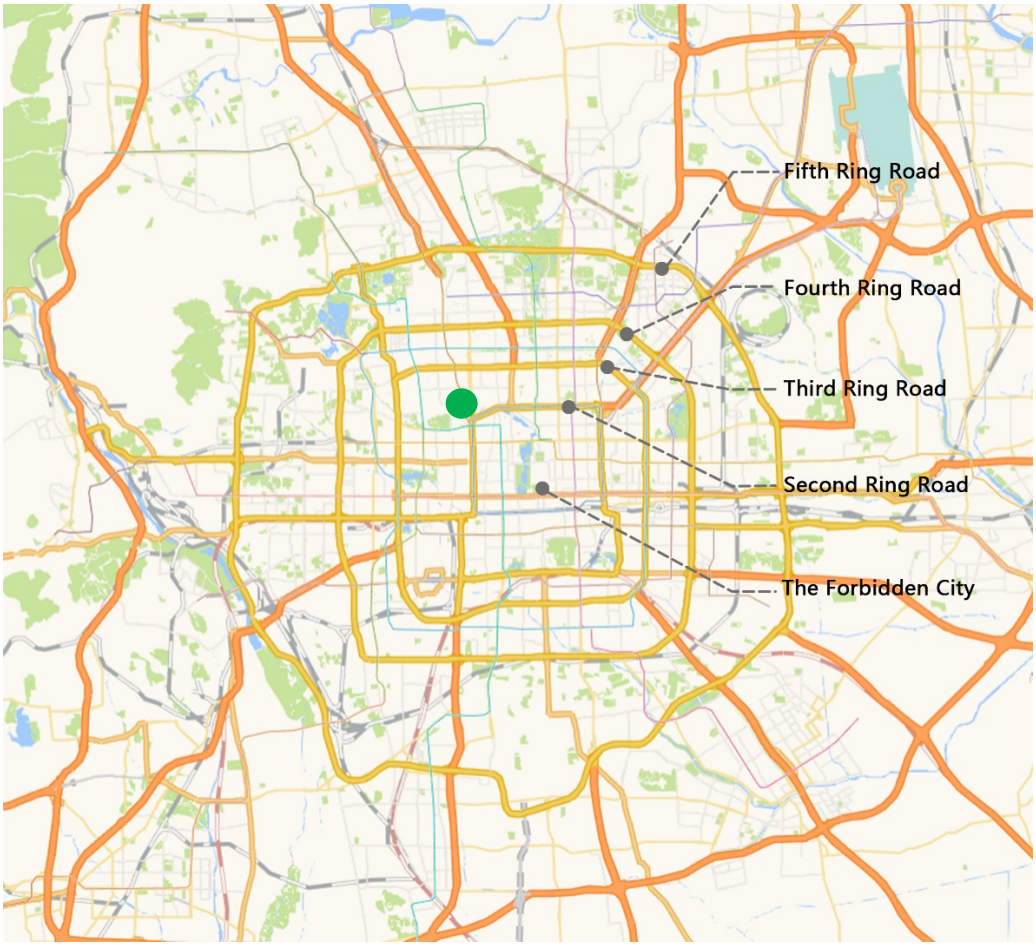


Figure 4: Map of downtown Beijing

The architecture in Beijing combines both modern and traditional styles. Figure 4 is a map of Beijing illustrating the fabric of the city. The Forbidden City is in the center, and the

[5] "Capital Facts for Beijing China," World's Capital Cities, accessed March 18, 2020, https://www.worldscapitalcities.com/capital-facts-for-beijing-china/.

[6] "District Of Columbia Population 2019 (Demographics, Maps, Graphs)," World Population Review, June 2019, https://worldpopulationreview.com/states/district-of-columbia-population/.

yellow rings are the ring roads surrounding the city. The first is called the Second Ring Road; there is no First Ring Road but some people assume that the river around the Forbidden City is the first ring. The rings developed quickly, and the closer to the city center, the denser the urban fabric.

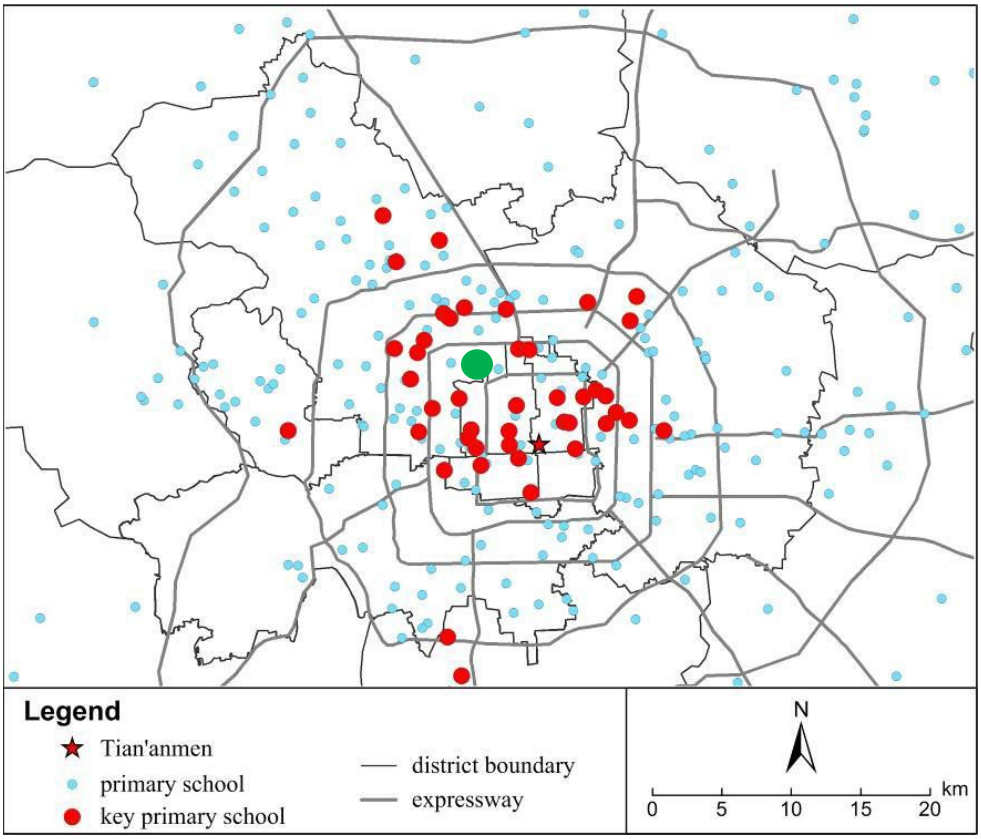


Figure 5: Spatial distribution of primary schools in Beijing[7]

There are 970 primary schools in Beijing. Figure 5 shows that the school density increases toward the city center. The research site is in the grounds of Beijing Jiaotong University (BJTU) located, between the Second and the Third Ring Roads (Green dots on

[7] Siqi Zheng, Wanyang Hu, and Rui Wang, "How Much Is a Good School Worth in Beijing? Identifying Price Premium with Paired Resale and Rental Data," The Journal of Real Estate Finance and Economics 53, no. 2 (2016): 184.

Figures 4 and 5). This site is positioned in the middle of the ring roads, close to the dense city area, and with limited development space. Most primary schools have the same issue, which makes this school an excellent prototype on with to conduct research.

This primary school is in the university, but it is open to all children who live in the area. The existing school consists of two three-story buildings and two playgrounds. The north building's first and second floors are for administration and art classrooms, respectively, and the third floor has several classrooms. The south building is the main building for regular classrooms. The two exits face away from the playground. Neither playgrounds is immediately accessible for students during the short recess. The total area of the two physical activity spaces is only 22,125 square feet. In this thesis, the site is redesigned to improve space performance and then analyzed to compare this new space with its current performance.

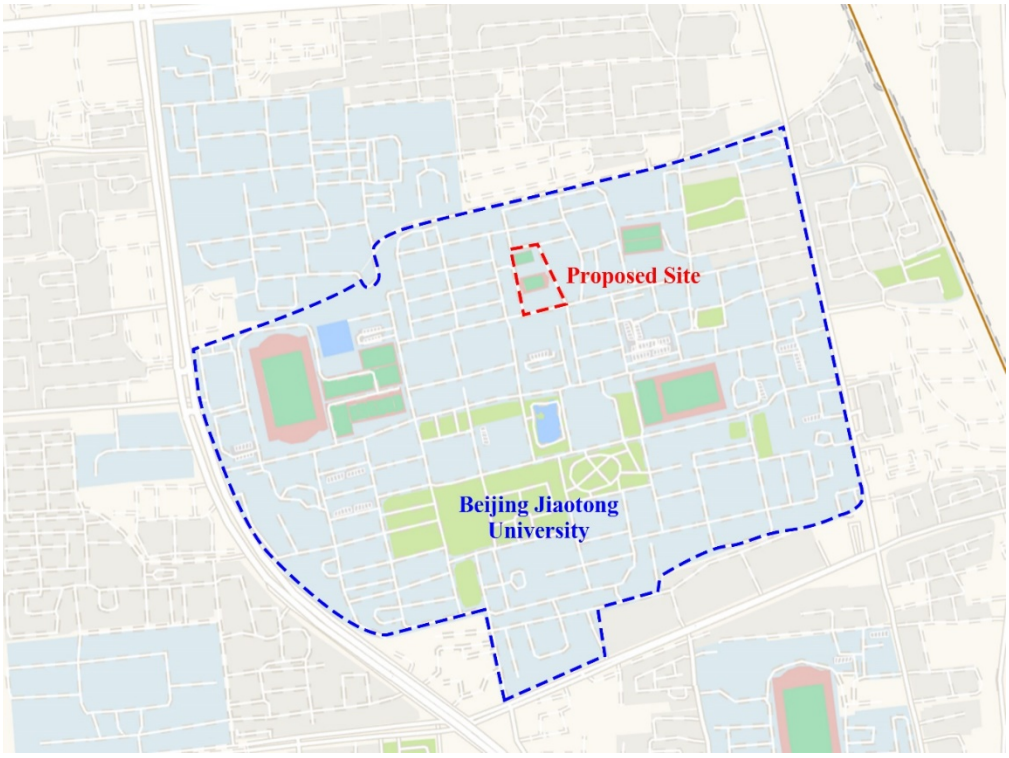


Figure 6: Site location

1.4 Problem Statement

Physical activity is vital for growing children contributing not only to physical and mental health, but also to academic achievement. Children spend most of their days at school. However, there is not enough time scheduled for physical activity, and the open spaces for elementary school students to do physical activity are limited in Beijing's urban area. Walking routes from the classroom to the playground are, often, too long to be readily accessible during a short recess.

Additionally, the inadequacies of the facilities and professional PE teachers are other problems that have caused a lack of interest in exercise among students. The above issues could be solved by increasing the Chinese Government's education investment in the future.

This thesis is a design-based thesis. It focuses on providing a solution to the limited space problem in Chinese primary schools to increase opportunities for physical activities and to provide good physical activity environments for children. The results could be used as a prototype for other primary schools in dense cities to solve the broader space issue in China.

2. Literature Review

This chapter reviews previous studies on the subject, revealing why physical activity is essential for students and why primary schools in Beijing need to be redesigned. This review presents data to illustrate the problem and to compare it with other counties. The theory used in this thesis is drawn from the studies in this chapter.

2.1 Physical Activity's Influences on Academic and Health

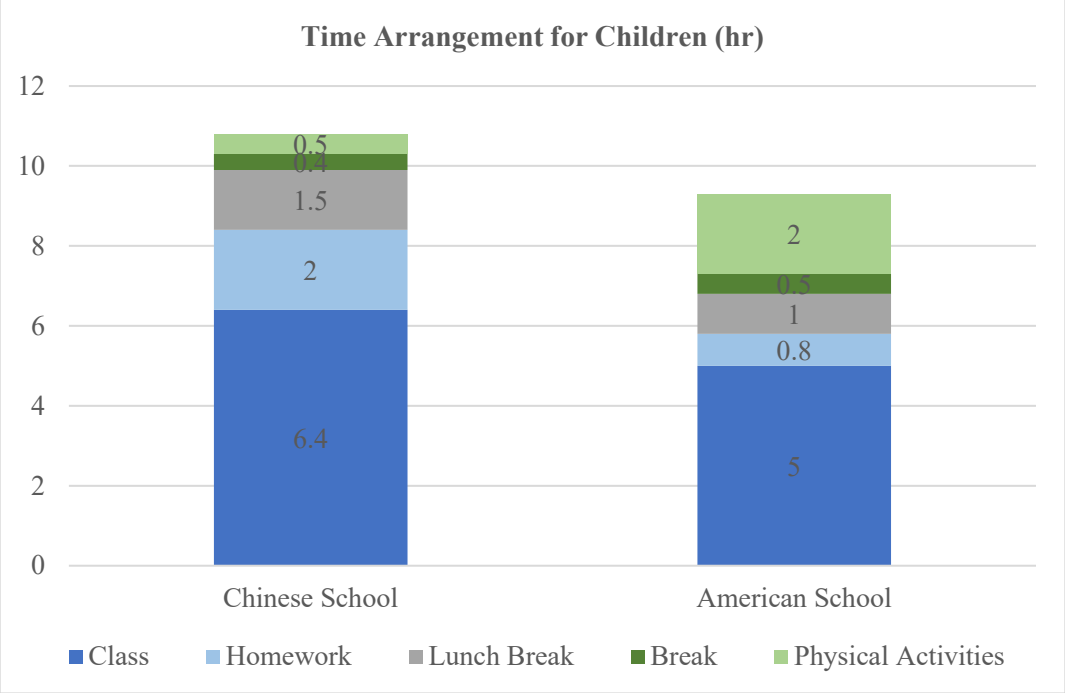


Figure 7: Time arrangements for children

Figure 7 illustrates the common time arrangements for children in primary school in China and America. The allotted time for study in China is more than in America, but the time for physical activity in China is only one-quarter of that in American schools.

A recent study in China reported that study time at primary school is greater than

previously. The time for study at school was 6.7 hours five years ago, and it is 8.1 hours today. The standard time for doing homework is less than one hour for Grades 4 to 6, but the report reveals that it exceeds this standard by 66%. According to the study, 66.3% of students do physical exercise for less than an hour every day during the week, and 7.6% do none at all. The report also indicates that 23.4% of students seldom walk outside to take an exercise break. In addition, 47.2% of students take after-school classes. The time available for students to exercise is decreasing, which causes health problems.[8]

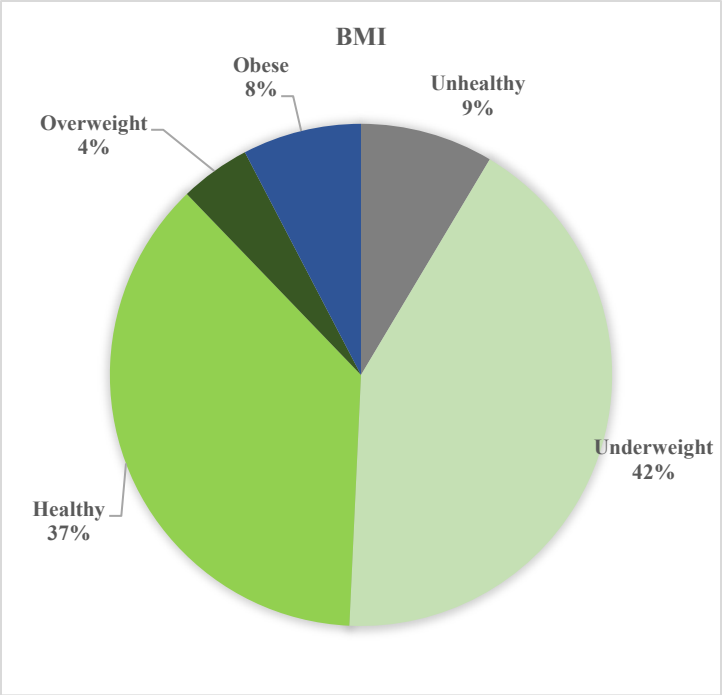


Figure 8: Weight issues

The primary problem is weight. According to Figure 8, 8% of students are obese, and

[8] Xiaopeng Wang et al., 从应试教育突围——中小学生“减负”问题研究报告, 21 世纪教育研究院 (Breakthrough from Examination-oriented Education: A Report on the Problem of "Reduce the Weight" of Primary and Middle School Students, 21st Century Institute of Education, China), 2018

42% are underweight. The issue of being underweight is more likely to be ignored, but it is also harmful to health. Student muscle volume is very low because of the lack of time spent on activities. As Beijing has developed, improvements to the living environment and transportation have restricted activity spaces, leading to people expending less energy in daily life, which has dramatically reduced the natural movement stimulation of children s growth and development.

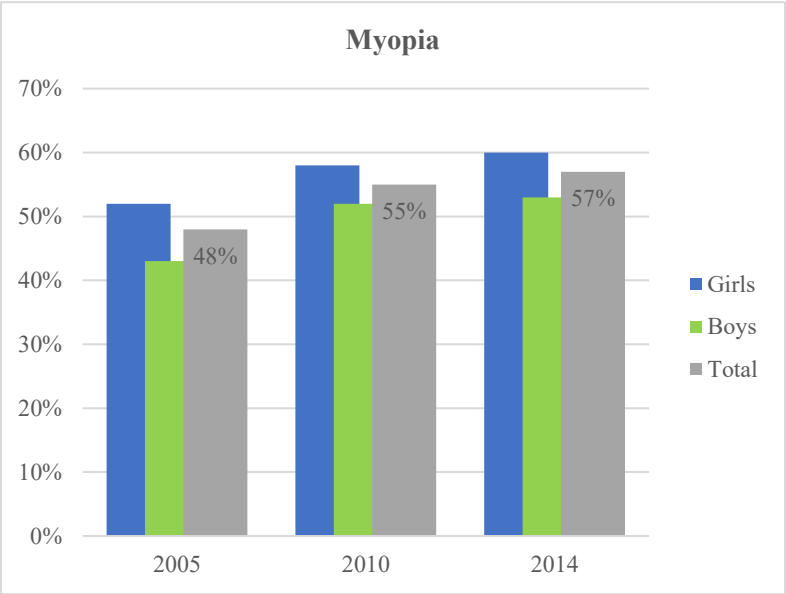


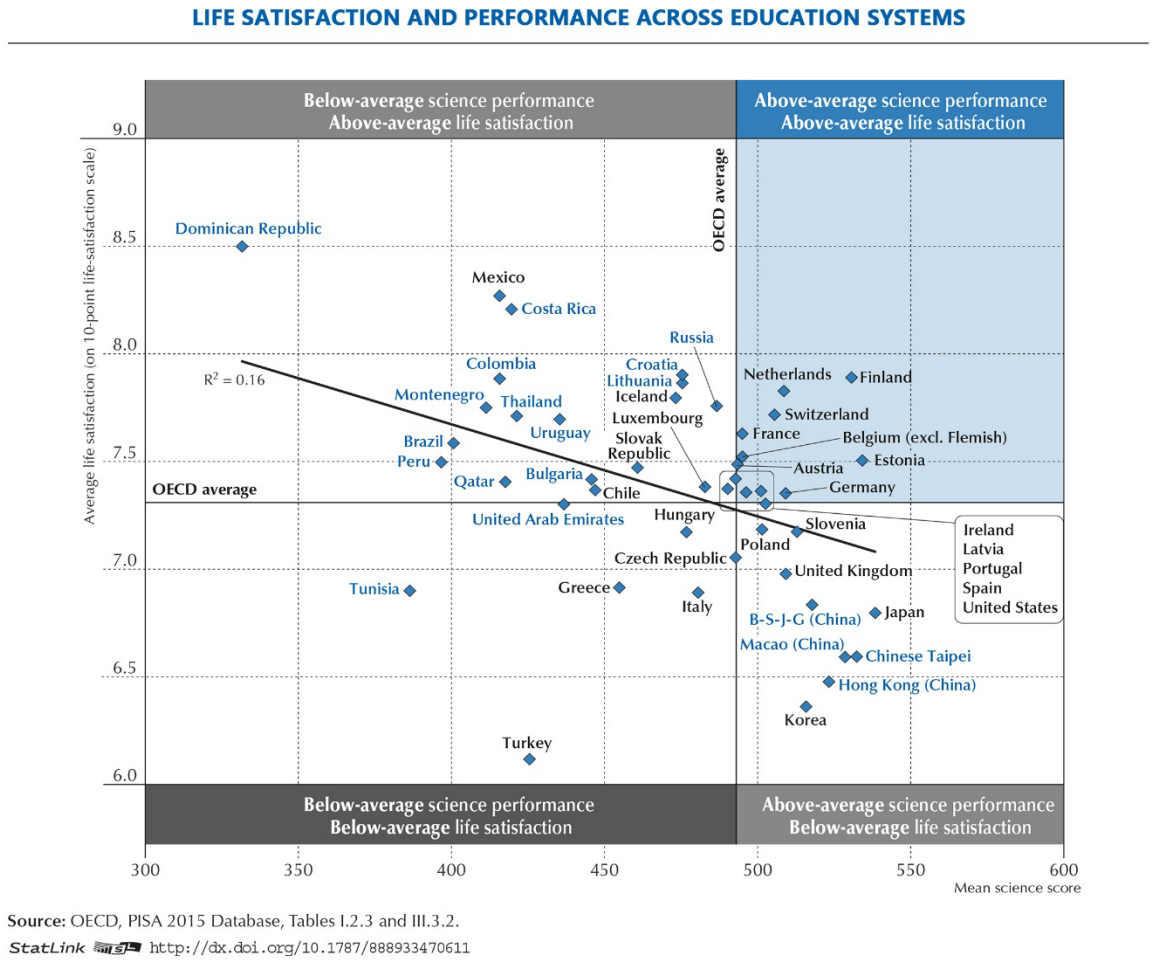
Figure 9: Myopia rates

The second problem is myopia. Figure 9 illustrates that more than 50% of students have myopia, and this rate is increasing annually.

Another significant issue is mental health. Suicide has become the third leading cause of death after traffic accidents and drowning among youth in China.[9] Schools in China

[9] Jian Wu et al., "我国青少年体质健康发展报告", 体育卫生艺术教育研究中心 (Sports Health Art Education Research Center, Sports Health Art Education Research Center, China Youth Physical Fitness Development Report, China) , 2008

pay great attention to students' academic achievements but overlook their physical and mental health. Increased exams coupled with less physical exercise creates stress in children.



Source: OECD, PISA 2015 Database, Tables I.2.3 and III.3.2.
StatLink http://dx.doi.org/10.1787/888933470611

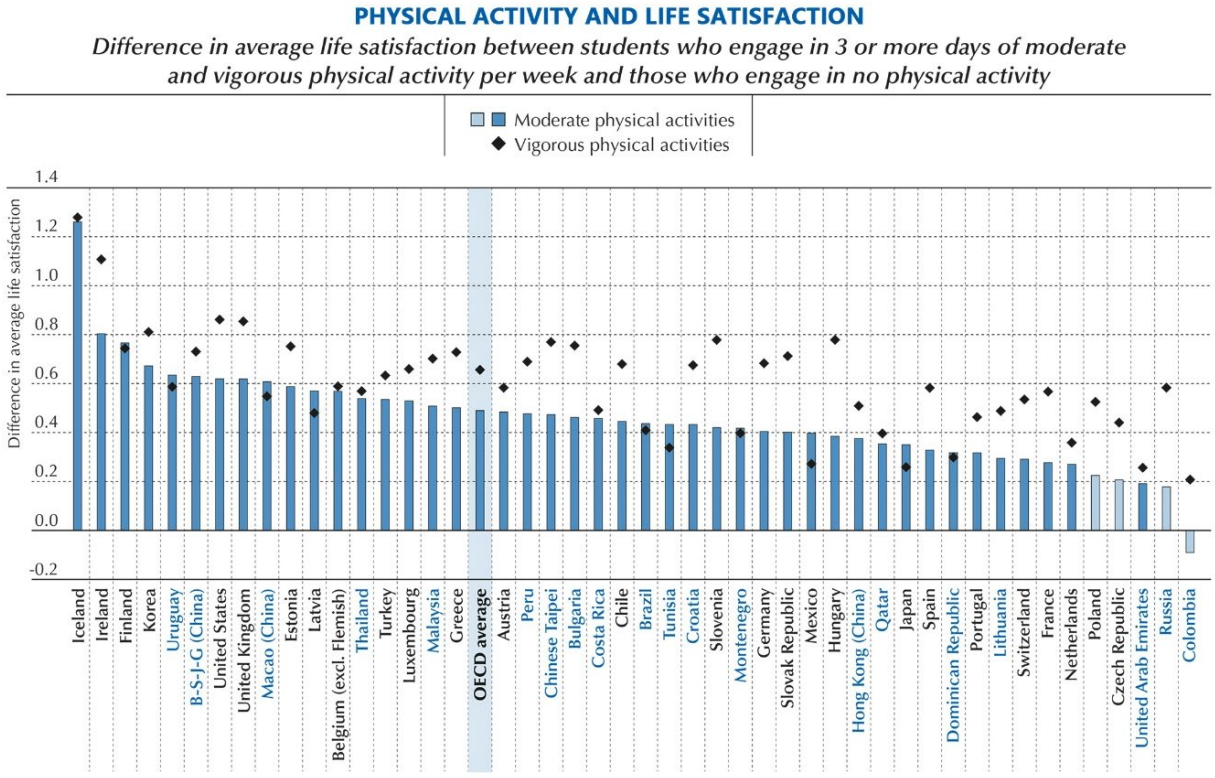
Figure 10: Life satisfaction and education performance

Figure 10 displays average science performance and average life satisfaction among OECD countries. China is above-average in science performance, but below-average in life satisfaction. Although academic performance is excellent in China, life satisfaction is poor.

Physical activities do not negatively affect study. The research argues that physical activities benefit children.

First, physical activities positively influence academics. Leslee, a scholar from the

University of Central Florida, researched the relationship between physical activities and academics. She found that physical activities enhance brain function, energy levels, body build/perception, self-esteem, and behavior, all of which improve academic performance.[10] Students' motor and coordination skills, which are necessary skills for academic success, can be developed through physical activities.



Note: All differences in life satisfaction relative to engaging in vigorous physical activities are statistically significant. Statistically significant values for moderate physical activities are marked in a darker tone (see Annex A3).

Countries and economies are ranked in descending order of the difference in average life satisfaction among all students who engage in moderate physical activities.

Source: OECD, PISA 2015 Database, Table III.11.16.

StatLink http://dx.doi.org/10.1787/888933472949

Figure 11: Physical activity and life satisfaction

Data from the OECD in Figure 11 reveal that physically active students report higher

[10] Leslee J Scheuer and Debby Mitchell. "Does physical activity influence academic performance." *The New PE and Sport Dimension 12* (2003): 4.

levels of life satisfaction.[11] The relationship between these two factors interrelates highly for both China and America. The life satisfaction of students who engage in three or more days of moderate physical activity is significantly different from students who do not do any physical activity.

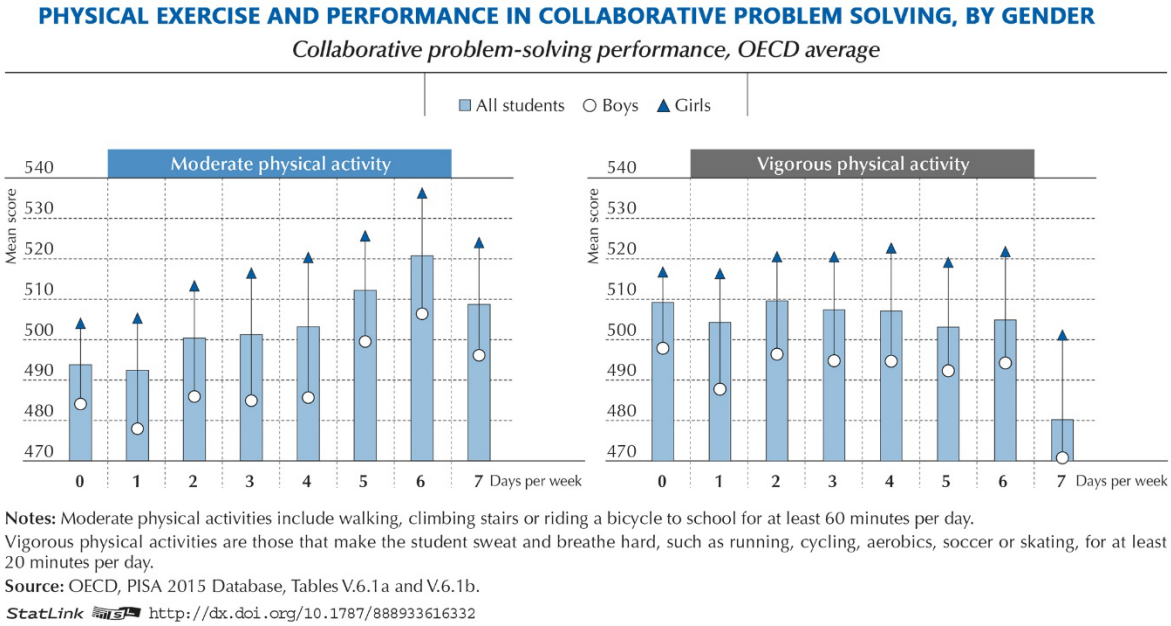


Figure 12: Physical exercise and performance in collaborative problem solving by gender

The OECD also researched "Collaborative problem-solving performance". The data in Figure 12 indicate that students who engage in more moderate physical activity or attend more physical education classes per week generally have more positive attitudes toward collaboration.[12] Children establish friendships with peers during the same activities and

[11] "PISA 2015 Results (Volume III) - Students' Well-Being - En - OECD," OECD, Paris, April 2017, http://www.oecd.org/education/pisa-2015-results-volume-iii-9789264273856-en.htm.

[12] "PISA 2015 Results (Volume V) - Collaborative Problem Solving - En - OECD," OECD, November 2017, https://www.oecd.org/publications/pisa-2015-results-volume-v-9789264285521-en.htm.

influence each other to become involved in sport.[13] Children learn how to interact with peers when they engage in physical activities. Then, they feel more confident in collaborating with other students on projects and activities.[14] Therefore, physical activity should be an essential facility in schools for students' health.

2.2 Urban Condition

Parents prefer to send their children to urban schools in China because the facilities and educational resources are better than in rural areas, and the schools are close to their places of work. However, school areas are limited in the city, and research has found that rural and suburban children are more active and spend more time outdoors than urban children because there is more space for physical activities.[15] Therefore, open space in urban primary is schools critical.

Tucker, a scholar in the health and environment field, researched how the physical environment influences physical activities in youths aged 11 to 13 in different countries. She assessed environmental impacts in the home and school neighborhoods. Her results show that

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[13] Allan Jay Fein, "Physical Environments and the Physical Activity of Youth." Order No. MQ59802, University of Alberta (Canada), 2000. https://ezproxy.rit.edu/login?url=https://search-proquest-com.ezproxy.rit.edu/docview/304644482?accountid=108

[14] Mark Vojnic, "Physical Activity and Student Focus in the Primary Grades." Order No. 1572397, University of Toronto (Canada), 2014. https://ezproxy.rit.edu/login?url=https://search-proquest-com.ezproxy.rit.edu/docview/1650601534?accountid=108.

[15] Gavin Sandercock, Caroline Angus, and Jo Barton, "Physical Activity Levels of Children Living in Different Built Environments," *Preventive Medicine* 50 (April 1, 2010): 193–98, https://doi.org/10.1016/j.ypmed.2010.01.005.

pleasant physical environments encourage physical activity.[16] Playgrounds need to improve to perform better as in city activity spaces.

Traditionally, school buildings are designed in a horizontal and dispersed pattern, and there is not enough horizontal space to support increased physical activities in the city. Vertical development can solve these space problems by creating a new type of learning environment in dense cities.[17] This approach involves complex spaces vertically instead of laying them horizontally. For example, a roof garden is a vertical development to increase green space and sustainability. Since Beijing's city guidelines require the maximum number of floors and the building ratio to be constant, outdoor space can be increased vertically. The benefits of vertical design provide more space to promote academic achievement and physical health.

2.3 Primary School Design Guidelines

The "中小学设计规范 (GB50099-2011)" ("Code for the design of school")[18] contains the building design requirements for primary, middle, and high schools (from first grade to twelfth grade) in China. The Code is a basic guideline for general schools. There is another

[16] Trish Tucker et al., "Environmental Influences on Physical Activity Levels in Youth," *Health & Place* 15 (July 1, 2008): 357–63, https://doi.org/10.1016/j.healthplace.2008.07.001.

[17] David Kim. "Vertical School: A New Typology for the City," 2017. https://search.proquest.com/pqdtglobal/docview/2015118063/abstract/1E760C6759A14253PQ/1.

[18] "中小学设计规范 (GB50099-2011)." 北京市建筑设计研究院, 天津市建筑设计院会, 中国, 2011. ("Code for the design of school (GB50099-2011)." Beijing Institute of Architectural and Tianjin Architecture Design Institute), 2011.

guideline for schools in Beijing, “北京市中小学校办学条件标准(建设部分-试行)” (“Standard for running primary schools and secondary schools in Beijing [Construction Section – Trial]”),[19] which contains more specific requirements. Both guidelines are used in the design in this thesis.

The guidelines state that, the land areas of small schools should consist of construction land, sports fields, green land, and event space. Green spaces in China do not always allow people to walk through them, so these open spaces cannot be used as physical activity or exercise spaces. School’s event spaces and sports field are, typically, combined into one space in the city and are the physical activity areas for children. In addition, schools in downtown Beijing can request variances for space limitation issues. As a result, many old schools and newer schools in the downtown area do not meet the requirements.

Outdoor playgrounds in China are required to have at least 200 meters of running track, including 60 meters of straight track. The minimum area for physical activity spaces for children is about 5,000 square meters or 53,819 square feet.

Planning Requirements				
	Area Description	SF	M^2	Notes
Commons				
1	Play Lot	3,000	278.7	800 SF (74.3 $M^{2)}$ per Learning Studio over 2
1	Play lot—Enclosed Storage	100	9.3	Pre-fabricated
2	Elementary/Middle -Outdoor play areas	21,780	2,023	1 to 100 students
2	Elementary/Middle -Outdoor play areas	43,560	4,047	101 to 500 students
2	Elementary/Middle -Outdoor play areas	87,120	8,094	501 to 1,000 students
2	Elementary/Middle -Outdoor play areas	130,680	12,141	1,001 + students

Figure 13: Space types and requirements for outdoor play areas

[19] “北京市中小学校办学条件标准(建设部分-试行)”, 北京市教育委员会,中国, 2018. (“Standard for running primary schools and secondary schools in Beijing (Construction Section-Trial)”, Beijing Municipal Commission of Education, China, 2018)

In America, according to Figure 13 from the Department of Defense Education Activity (DODEA),[20] elementary/middle school playgrounds require 87,120 square feet for 501 to 1,000 students, whereas play areas in Chinese primary schools are much smaller. Thus, physical activity spaces are limited in Chinese elementary schools, especially in urban areas.

This project proposes redesigning school spaces to increase physical activity in a highly efficient way and become a new guide for school design in China. The Government pays attention to the high standards of student grades and teacher evaluations but overlooks school building design and planning. Physical health should be considered part of the educational system[21] because it improves academic and emotional performance, thereby helping to meet China's goals.

2.4 Other Considerations

2.4.1 Context

It is not only school design that influences children, but also the school neighborhood. School buses are not mandatory in China, so parents and children choose alternative methods of traveling to school, such as public transportation, cycling, walking, or by car. Seventy percent of students are escorted to school by their parents, and about 29% of students travel to

[20] SPACE TYPES & REQUIREMENTS, Education Facilities Specifications, DODEA, 2014.

[21] C. Tanner, "The Influence of School Architecture on Academic Achievement," *Journal of Educational Administration* 38 (October 1, 2000): 309–30, https://doi.org/10.1108/09578230010373598.

school alone.[22] The commute is associated with the built environment, which relates to the site environment. Drop-off and pick-up areas and cycle parking lots should be considered in the design to avoid unduly affecting those who reside nearby.

Furthermore, regarding the context, since most neighbors are residents, more interaction with the community will promote a better relationship with them. The school could raise funds by renting out spaces for community activities after school and on weekends.

2.4.2 Teaching Style

It is helpful to consider education in depth the status of the teaching and learning model in the 21st century. Chinese students outperform American students in various main academic topics in primary school, and the Chinese teaching style is completely different from the American teaching style. American students study in a free and comfortable environment that helps them think creatively and collaborate well with others. The complex world of communist China and its competitive methodology helps raise highly efficient, obedient, intelligent children, but also creates barriers to individualism and creativity.[23] Both the Chinese and American teaching styles have their advantages and disadvantages, but a

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[22]Lin Lin and Lingling He, "Overweight, Commuting to School, Urban Design in Chinese School Neighborhoods," *Journal of Transport & Health* 3 (June 1, 2016): S19, https://doi.org/10.1016/j.jth.2016.05.055.

[23] Lenora Chu, LITTLE SOLDIERS: An American Boy, a Chinese School, and the Global Race to Achieve. Austin, United States, 2017.

balanced style is the best.

2.4.3 Sustainability

To be a sustainable country, education is one of the most critical aspects. School buildings with sustainable features save energy and educate children about 'green' buildings while they are young. In a developing country such as China, the sense of sustainability is not fully formed, but it is urgent. Green building design will provide students with a sense of sustainability. The performance of daylight provision, solar application, ventilation, cooling and heating systems, etc. are also related to study behaviors.[24] In addition, the philosophy of the school plan will drive the development of the community. Sustainable schools help to promote the success of sustainable communities.[25] This school design will contribute to the development of Chinese green buildings.

2.5 Case Study

As the city of Beijing grew, school size decreased. The effective use of space contributes to the learning environment. Therefore, how to design space for students is important. Some articles closely related to this topic are reviewed, below.

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[24] Giacomo Chiesa and Mario Grosso, "Sustainable School Buildings: Designmanagementmonitoring, Results and Weaknesses. the Case Study of the High School 'L. Orsini', Imola," *Techne : Journal of Technology for Architecture and Environment* 9 (April 1, 2015): 247–55, https://doi.org/10.13128/Techne-16126.

[25] Gareth Roach, "Schools for Sustainable Futures: A Study into the Concept of Bespoke Primary School Design in South Wales." M.Phil., Cardiff University (United Kingdom), 2011. https://search.proquest.com/docview/1685021352/1F954BF542994E6FPQ/38.

2.5.1 Vertical School: A New Typology for the City

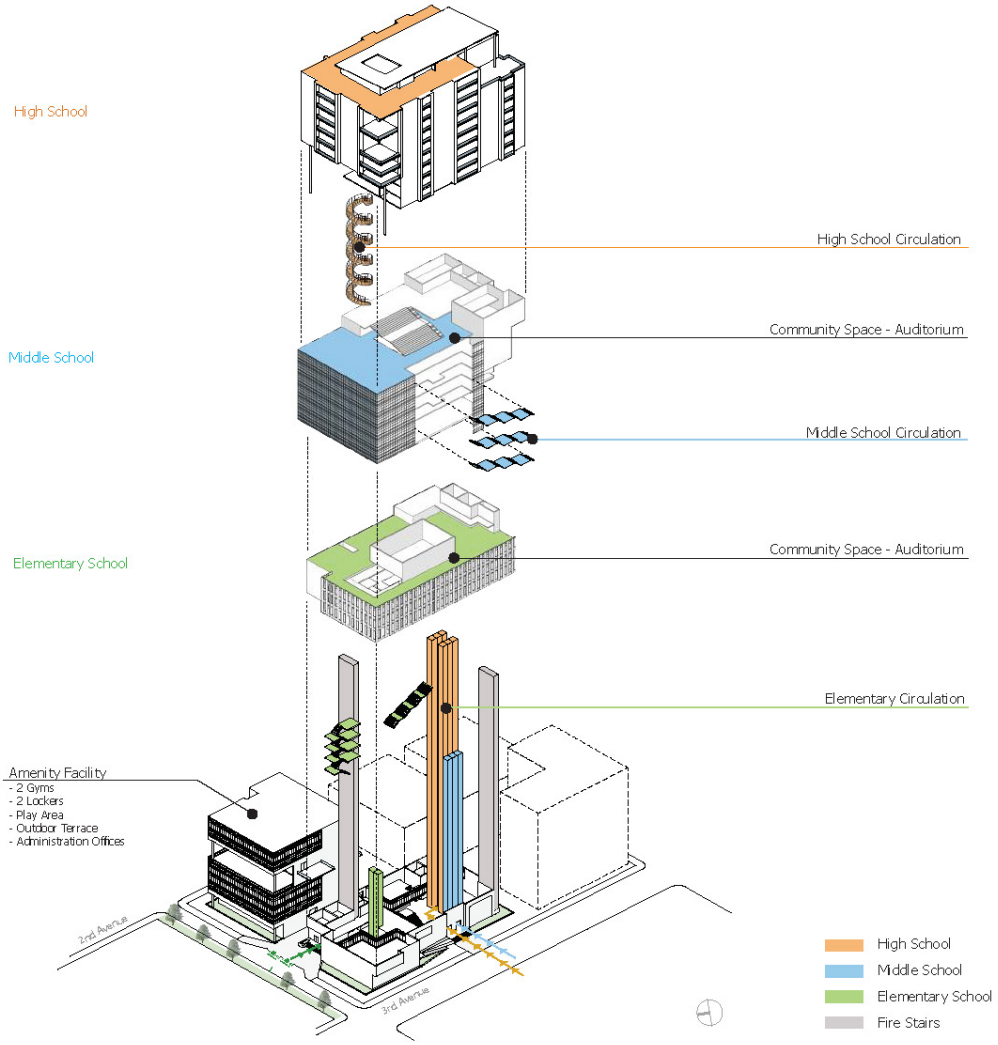

Figure 14: Case Study 1, Vertical School

The first case is "Vertical School: A New Typology for the City,"[26] which is a design-based thesis. In the article, the author first introduces the background information. The second part explains why the Vertical School is needed and its benefits by combining the current

[26] David Kim, "Vertical School: A New Typology for the City." Order No. 10688042, University of Washington, 2017. https://ezproxy.rit.edu/login?url=https://search-proquest-com.ezproxy.rit.edu/docview/2015118063?accountid=108.

situation and future trends. The third chapter discusses site selection and the program's organization and design principles. The final two chapters contain the design proposal, which is the most important part of study. The Vertical School is a high-rise building combining elementary, middle, and high schools to maximize student learning experiences. The space arrangement are in a highly efficient way in this case study. There are many analyses of space connections and valuable design elements that are quite helpful for school design.

The differences between the Vertical School and the proposed design in this thesis are the context and the scale. The Vertical School is in a highly dense building environment, and it occupies a tiny site. The goal of this case study is to provide more educational opportunities in the city. Therefore, it overlooks the physical activity spaces in the buildings. There are limited outdoor spaces for exercises in an additional building. It is an eight-story building that is far away from the higher-grade students including indoor gyms and outdoor terrace. All students need physical activity spaces, and the volume of people in a high-rise building could be a safety issue.

2.5.2 Tongji University Affiliate Elementary School

Figure 15: Case Study 2, Tongji University Affiliate Elementary School 1

The second case study is an elementary school design in China-Tongji University Affiliate Elementary School. The architect is Chinese designer Yuyang Liu. The design follows the context of the original site, creating connected spaces through courtyards of different scales and different types of enclosures according to functional demands. The school is integrated into the townscape through the design of the buildings' scale and buffer space.[27]

[27] "Tongji University Affiliate Elementary School / Atelier Liu Yuyang Architects." ArchDaily, March 20, 2018.

Figure 16: Case Study 2, Tongji University Affiliate Elementary School 2

There is ample analysis of the topography, space connections, and buildings. The space design collaborates with the topography and is especially worth studying. The uneven topography means that the path toward the buildings consists of slopes, grass steps, and concrete risers. The design retains the topography as much as possible in its infrastructure. In addition, there are many courtyards and open spaces at different levels, through which the terrain interacts with the buildings. It increases the sense of depth and makes the campus energetic.

2.5.3 School of Architecture, Crescent University

Figure 17: Case Study 3, School of Architecture, Crescent University 1

The building of the School of Architecture at Crescent University is distinctly recognizable due to its stepped terraces. The building was developed on a small site but provides space for intense activity, gathering, and socializing.[28]

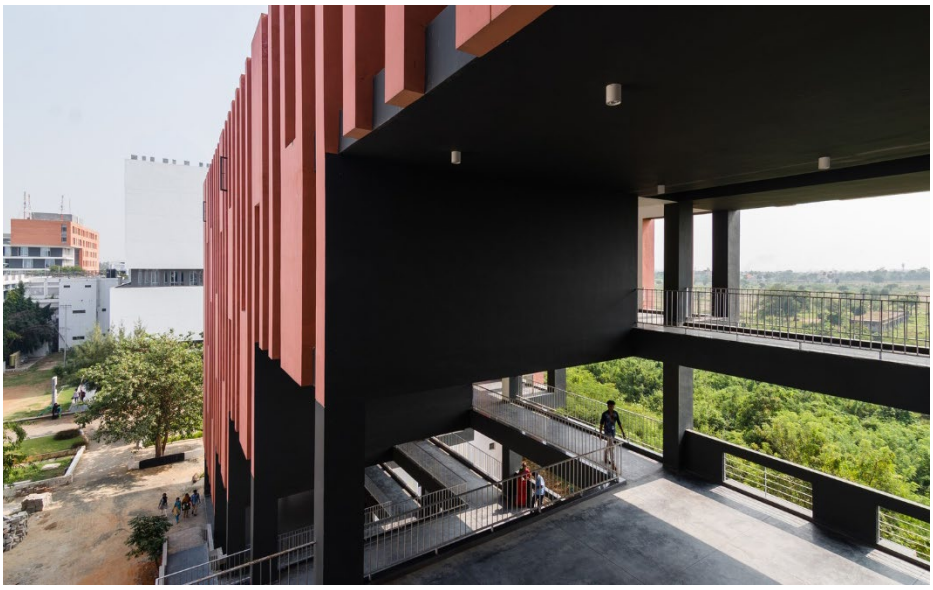

Figure 18: Case Study 3, School of Architecture, Crescent University 2

[28] "School of Architecture, Crescent University / architectureRED", ArchDaily, 2019.

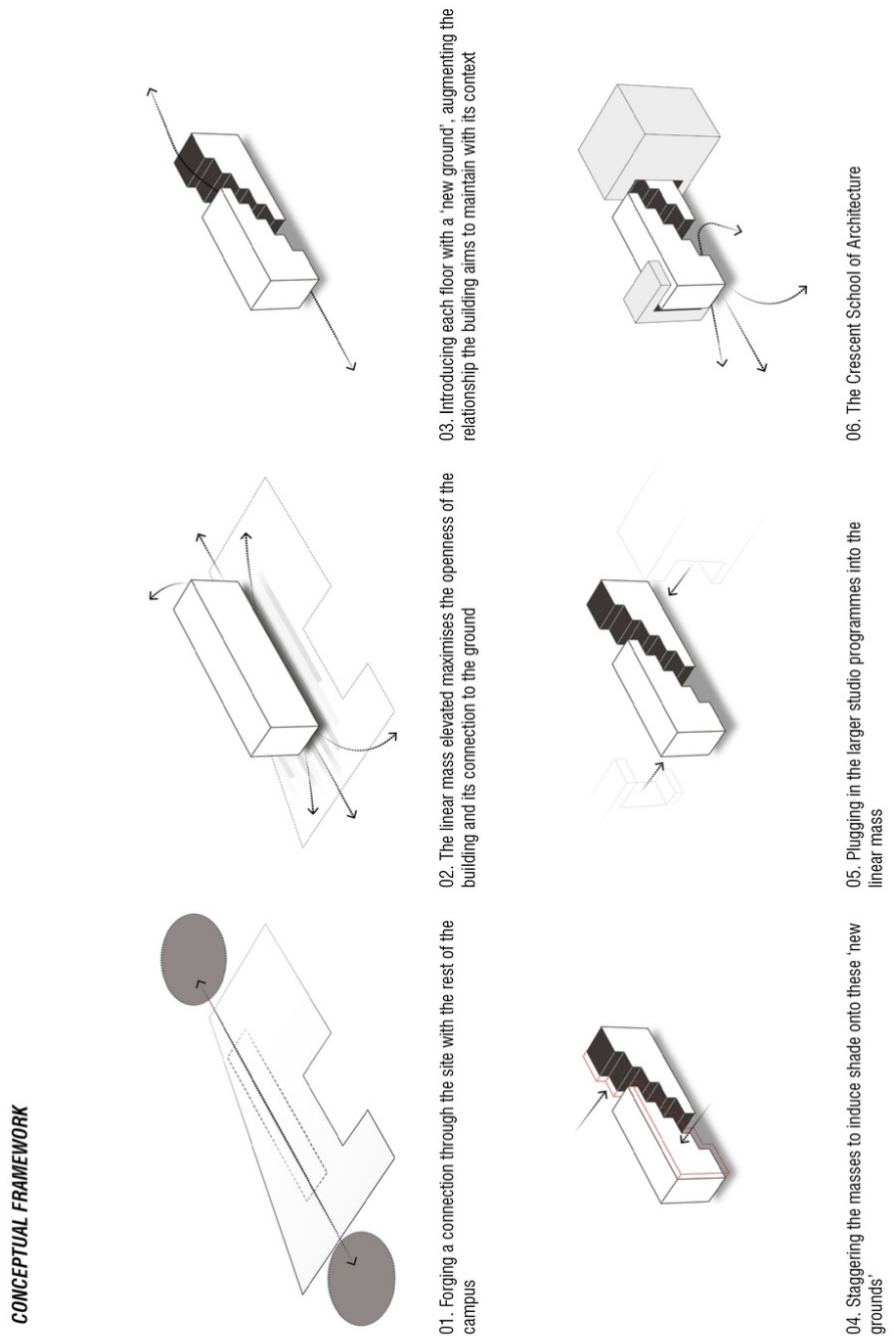

Figure 19: Case Study 3, School of Architecture, Crescent University 3

The School of Architecture building has three parts. The middle section is the highlight of this case. It functions as the studio building and the connection for each space. Instead of endless corridors, these staggered piazzas ease the circulation of people. Students

are welcome to use this space for various events.

Figure 19 is the conceptual framework of the design connecting the two existing buildings as a linear mass. To create “new ground” for each floor and maintain its context, the building is split into two parts by the stepped terraces. Subtle pulls and pushes of the building masses induce shadows onto the “new ground.” Figure 20 displays the lighting and shading effects in the outdoor space.

Figure 20: Case Study 3, School of Architecture, Crescent University 4

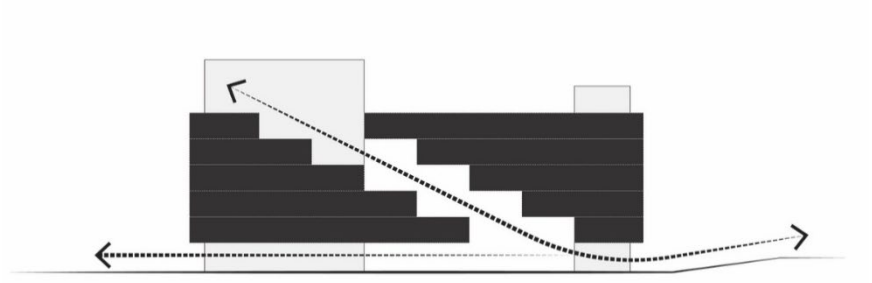

Figure 21: Case Study 3, School of Architecture, Crescent University 5

The first floor is open and offers multiple access points and shaded areas as illustrated in Figure 21. The design extends the plane into the building to create open space at

each level. By splitting the building, the building mass is lighter, wind can blow through, and light can pass through. The architecture studio located around the stepped open spaces encourages students to interact with nature.

Climate is one of the critical elements that can influence the result. Although this build has a good space arrangement, the exposed surfaces are enormous. The average temperature of the project's city (Chennai, Tamil Nadu, India) is 84°F,[29] which is a different climate zone compare with Beijing. In this thesis design process, rationally arranging the outdoor spaces should be considered.

[29] Climate & Weather Averages in Chennai, Tamil Nadu, India, timeanddate.com, https://www.timeanddate.com/weather/india/chennai/climate

2.5.4 Chongqing Nankai LiangJiang Secondary School

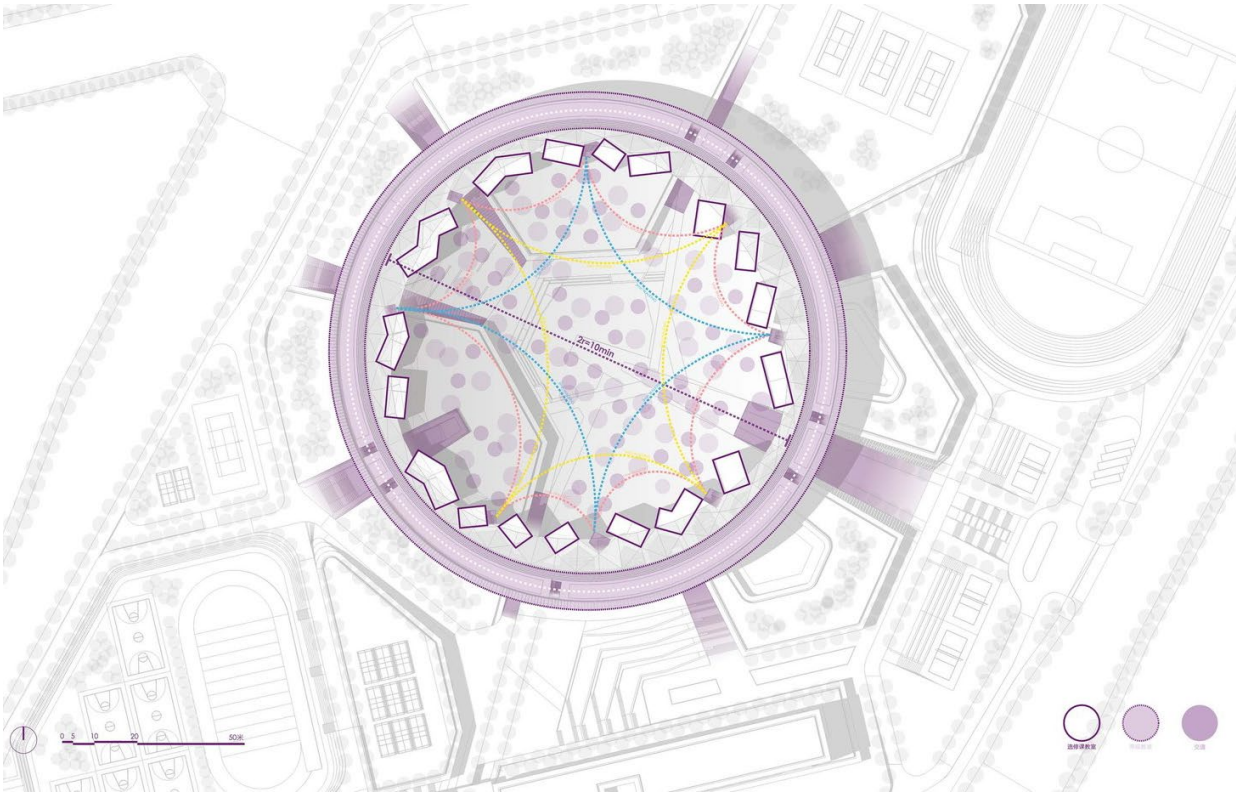

Figure 22: Case Study 4, Chongqing Nankai LiangJiang Secondary School 1

The main building in Chongqing Nankai LiangJiang Secondary School is a circular "spaceship-like" shape. It consists of six sections: junior, senior, international, laboratory, administration, and art. All the sports venues are located at the outside of the ring to act as a buffer between the classrooms and traffic. The fan-shaped sections mean that students can use an efficient class transfer route and have fun passing through the central garden. The longest distance is a 10-minute route across the diameter of the building. Other paths are shorter, but all are in the natural environment. Both the inner and outer sides of the circle buildings have plenty of physical activity spaces.[30]

[30] Chongqing Nankai LiangJiang Secondary School / gad, ArchDaily, 2018.

Figure 23: Case Study 4, Chongqing Nankai LiangJiang Secondary School 2

The rooftop of the academic building is a 628-meter footpath, allowing students to exercise and develop their bodies. The advantages of the roof are ample open space, sufficient sunlight, and proper ventilation. However, roof space could be a highly dangerous place for student activity. Storm and snow load, occupant load, mechanical equipment, and safety guards should be designed according to strict standards.

Figure 24: Case Study 4, Chongqing Nankai LiangJiang Secondary School 2

Most of the stairs in the school are exposed to the outside. Figure 24 is a photo of large platforms on each level close to the stairs. Their platform's shapes are irregular and change vertically. Students can choose to explore the space and play with friends in these places or go to the ground level, depending on the recess time allowed.

2.5.5 KB Primary and Secondary School – Interior Design Case Study

This project is a public secondary school campus that was renovated as a private primary and secondary school in Japan.[31] Some of the interior designs are important to consider for this present thesis.

Figure 25: Case Study 5, KB Primary and Secondary School 1

Spaces under stairs are traditionally used for storage or waste as they are usually narrow and irregular and difficult to arrange. The designer of the KB School uses this space

[31] "KB Primary and Secondary School / HIBINOSEKKEI, Kids Design Labo, Youji no Shiro", ArchDaily, 2019.

for rock climbing. Children can play there and exercise. The space is within the building and near to the stairs, so students do not need to spend too much time getting here.

Figure 26: Case Study 5, KB Primary and Secondary School 2

Figure 27: Case Study 5, KB Primary and Secondary School 3

This indoor platform shown in Figure 26 and 27 is combines traditional and modern

Japanese architecture. The addition of glass to enclose the building creates a warm, indoor activity space. Children can rest here with sufficient daylight.

Figure 28: Case Study 5, KB Primary and Secondary School 4

Another detail is this small library in the hallway. This library for primary school students does not occupy much space. It could be in the hallway or a small area, where it is quiet and cozy. Considering the scale of the primary school, utilizing space efficiently can add more functions for the student.

2.5.6 Conclusion from the Case Studies

Vertical space development and overlapping spaces are successful characteristics of "Vertical School: A New Typology for the City." The arrangement of outdoor space should be designed to adapt to local conditions. "Tongji University Affiliate Elementary School" has multiple types of outdoor space. They are quality spaces providing good lighting and a variety of conditions (e.g. indoor, outdoor, covered, open). "Chongqing Nankai LiangJiang Secondary School" highlights the quality of access to spaces. The "School of Architecture, Crescent University" provides the outdoor activity spaces on each floor. Open physical activity spaces could be part of building design that reduce the distance from the classroom to the ground field, and do not occupy the ground space. The building should not be a box to trap students. The "KB Primary and Secondary School" uses indoor physical activity facilities to promote physical activity. When the weather is poor, students can stay inside to play. Other small interior spaces could be efficiently re-functioned.

The above projects provide necessary spaces for students, which helps to define the current design program. It includes the different classrooms, administration offices, and facilities recommended for primary school students. The connection and location of each space are also important. For example, the music room should not be close to classrooms because of its sound impact. Furthermore, both indoor and outdoor space design determine the success of the solution.

2.6 Theory

This thesis is design-based. It focuses on the design of physical activity spaces in a primary school in a dense urban area. The goal of the design is to promote physical activity to improve both the academic achievement and the physical health of children. The design of outdoor open space is primary, and the design of the indoor play area is secondary. Physical activity spaces should be located every two stories, and the travel distance to them should be less than in the existing building. The design criteria concern the amount of open space, the quality of the physical activity space, and the quality of access to the open space.

3. Methodology

This chapter focuses on the design to solve the research problem. A site analysis helps to study the context and climate (e.g. shade, light, ventilation, noise, safety) in this area to find a suitable location for physical activity. Based on the literature review, case study, and analysis, a program is prepared to include all the elements for the next step, design. The final design proposal is compared with the existing design to illustrate its improvements. The daylighting analysis tests whether the outdoor open spaces have sufficient natural light for physical activities.

3.1 Criteria and Evaluation

The proposed design focuses on, but is not limited to, enhancing the existing spaces, increasing the area of the outdoor activity spaces, improving the quality of the indoor and outdoor spaces, multiple types of physical activity spaces, and reducing the time spent walking to the outdoors. The design proposal is then evaluated by comparing it with the existing design to determine whether the design provides successful solutions.

3.2 Site Analysis

3.2.1 Site Condition

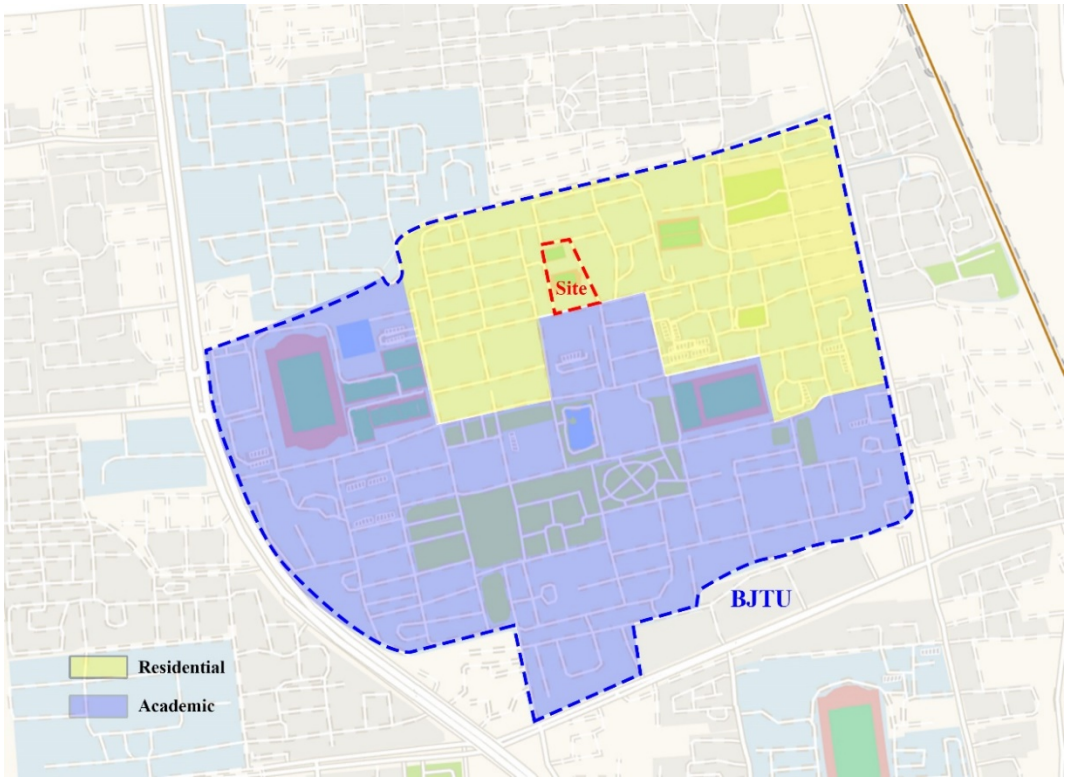

Figure 29: BJTU site map

There are no major topography changes at the BJTU site. The site of the primary school is entirely flat. On the BJTU campus, the north section is the residential community for professors and their families, and the south section is the academic campus. The primary school is in the residential area. Vehicles are allowed throughout the college, but there is an access control system at each entrance. Bicycles and pedestrians are the most circulated traffic.

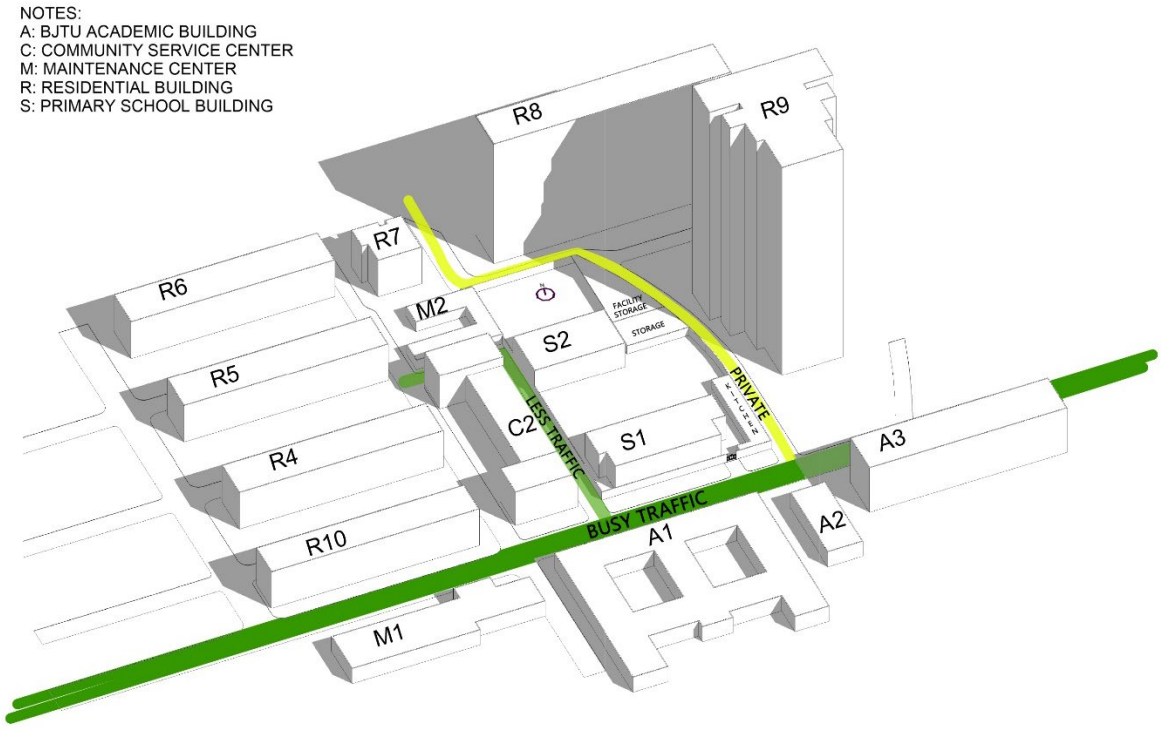

Figure 30: Primary school three-dimensional(3D) vicinity map

The entire primary school campus is fenced with solid walls about 10 feet high. The two main buildings (S1, S2) in the school are three stories. The only gate is on the south side, facing the BJTU academic buildings. The north and east roads are private, meaning school entrances cannot be built there. The south side has busy traffic, especially during the school's starting and ending hours. The west road is narrow, but it is a potential location for a new gate.

There are no adjacent buildings around the campus, except in the northwest corner. The building adjacent to campus is a maintenance center (M2), a one-story building with no windows on the campus side. Two further buildings on campus are the kitchen and storage. There is also a sunshade area for storage.

Figure 31: Campus surrounding photos

Buildings R8 and R9 are residential buildings, while Building C2 is a community service center. The new design will influence the buildings around it in terms of shading, ventilation, and noise, but the influence will be subtle because of the surrounding road barrier.

3.2.2 Climate Analysis

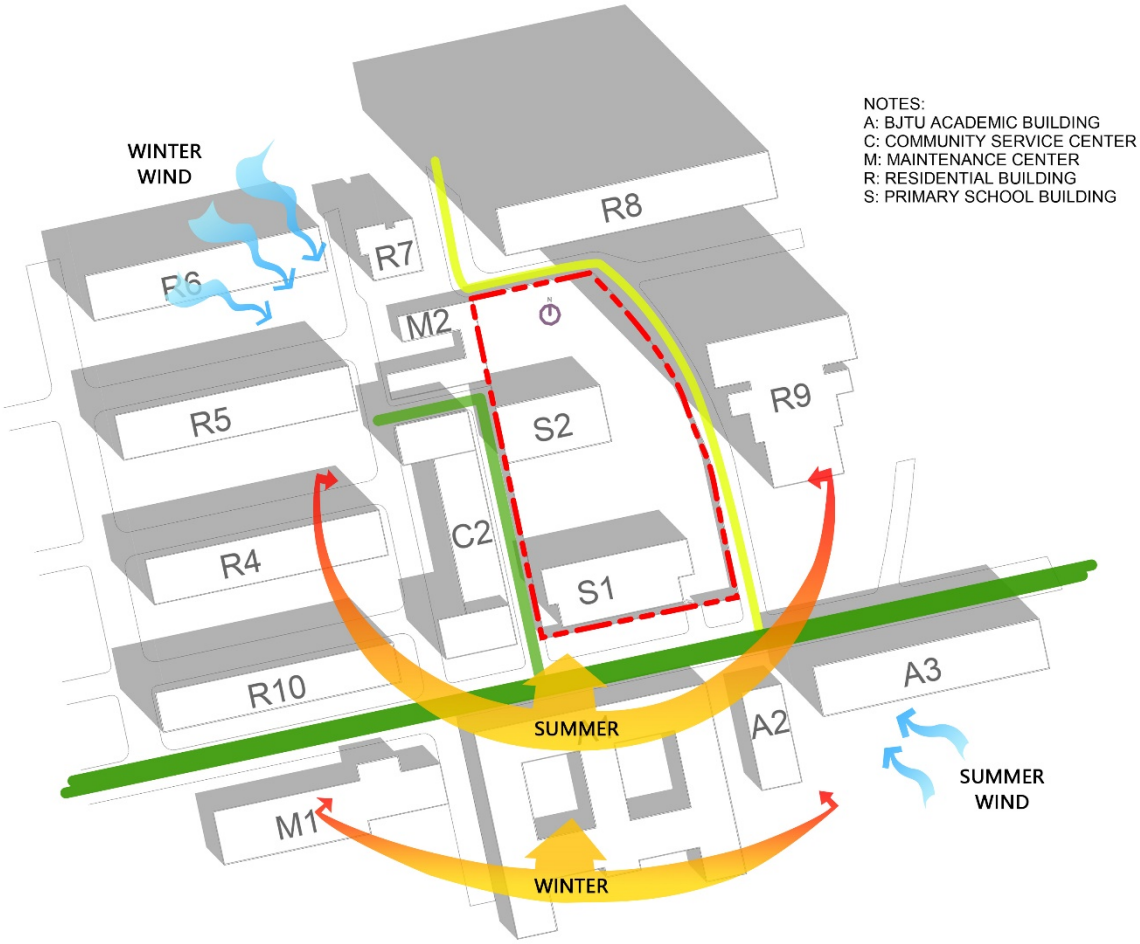

Figure 32: Site analysis

Beijing is in a temperate monsoon zone with four distinct seasons. In the summer, the average temperature is 79°F and the prevailing wind comes from the Pacific Ocean (southeast), which brings humid air to the land with precipitation. In the winter, the average temperature is only 25 °F and the prevailing wind comes from inland (northwest), which is dry, and the precipitation is low. Spring and summer are short but have moderate climates.[32]

[32] "Beijing Climate," Tour-beijing.com, accessed January 21, 2020, https://www.tour-beijing.com/chinese/climate.php.

Spring is rainy with a large temperature range. The days are warm and the nights are cold, which is suitable for physical activities at school. Indoor activities can be considered for rainy days. Fall is the most comfortable season. The temperature is suitable, and the daylight is sufficient. Indoor and outdoor activities are encouraged. The heavy rain in July and August does not affect students because schools are closed for summer vacation. Summer and winter are critical seasons. The buildings need to adapt to the cold winter and the warm summer.

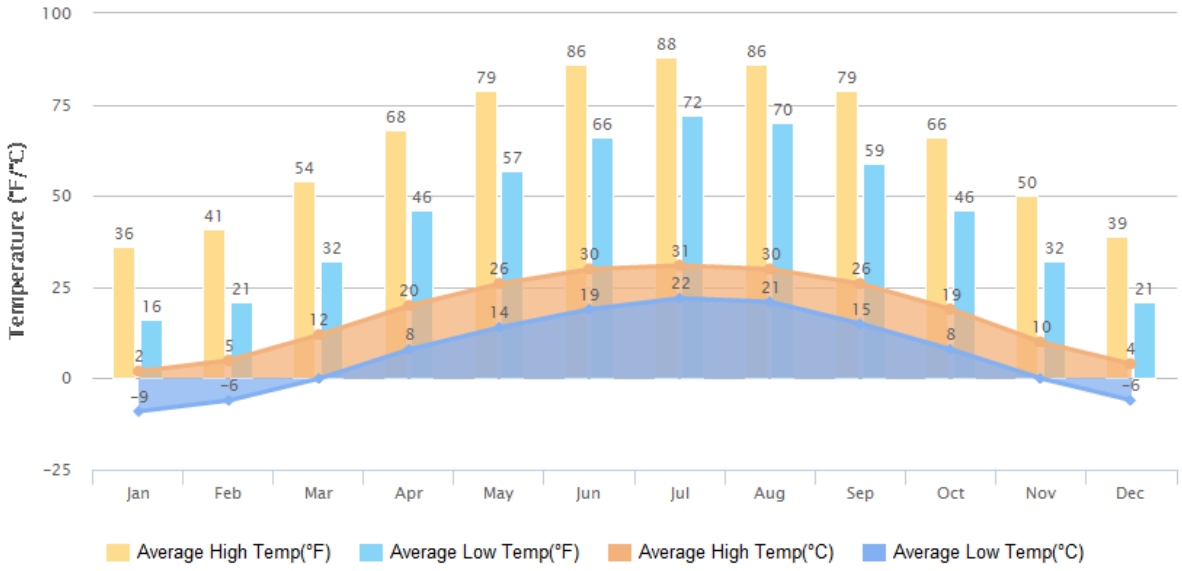

Figure 33: Temperature[33]

3.2.3 Shading Analysis

Shading influences outdoor activities in different seasons and at different times. This shading analysis is intended to select the proper location for the running track, which will be the main event space and assembly exercise space during the long break between classes. The times chosen for analysis are 10:00 a.m., 12:00 p.m. and 2:00 p.m. Student take a long break

[33] "Beijing Weather," Travel China Guide, accessed March 21, 2020, https://www.travelchinaguide.com/climate/beijing.htm.

at around 10:00 a.m., 12:00 p.m. is when the lunch break begins, and 2:00 p.m. is the time for afternoon exercise and after-school activities. Both the on-site buildings and the surrounding buildings are analyzed.

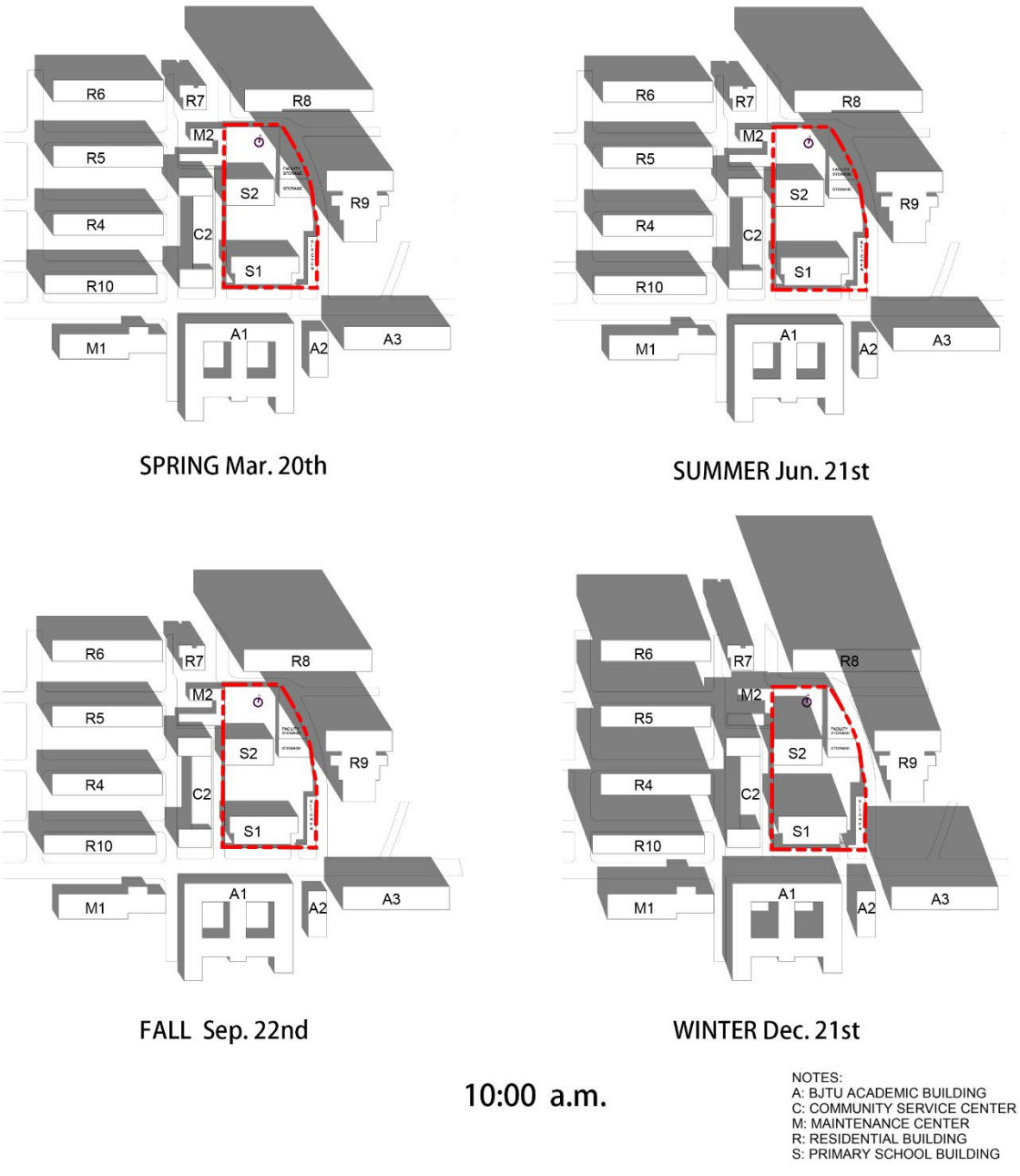

Figure 34: Shading pattern at 10:00 a.m.

At 10:00 a.m., building R9 shades the northeast part of the site in the summer, reducing the exposed area in the hottest season. In winter, the building in the south part of the

school is influenced most, but the northeast campus is warmed by direct sunlight. The shading of surrounding buildings in the spring and fall has little effect on the ground. Therefore, the northeast is the best place for outdoor activity at 10:00 a.m.

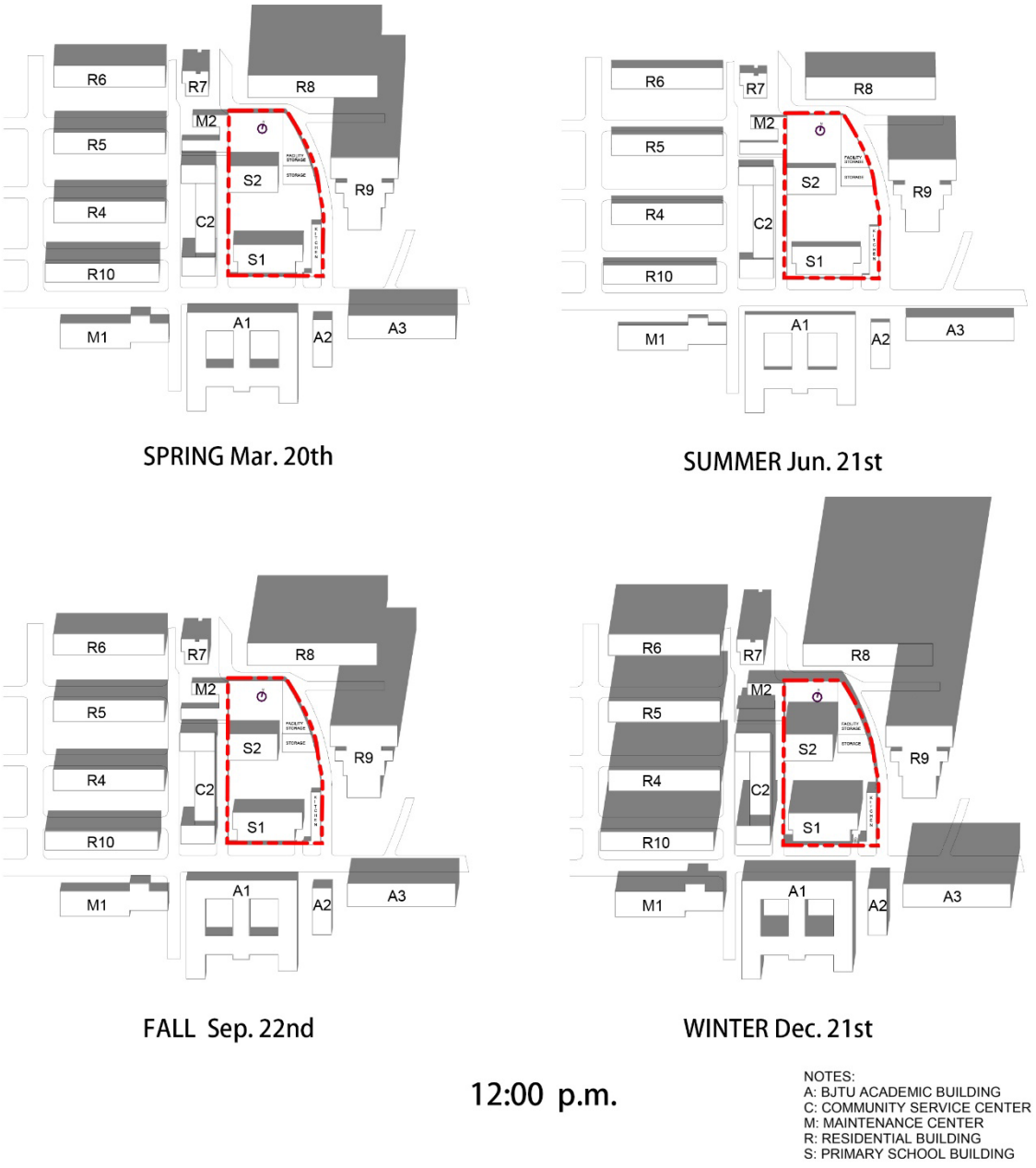

Figure 35: Shading pattern at 12:00 p.m.

There is almost no shading at 12:00 p.m. in the summer. A cover for outdoor activity

space or indoor activities should be considered during lunch break. The shading toward the north of the building on the site will influence the exposed area in the winter. Spring and fall present acceptable shadings. The surrounding buildings do not affect the site at noon.

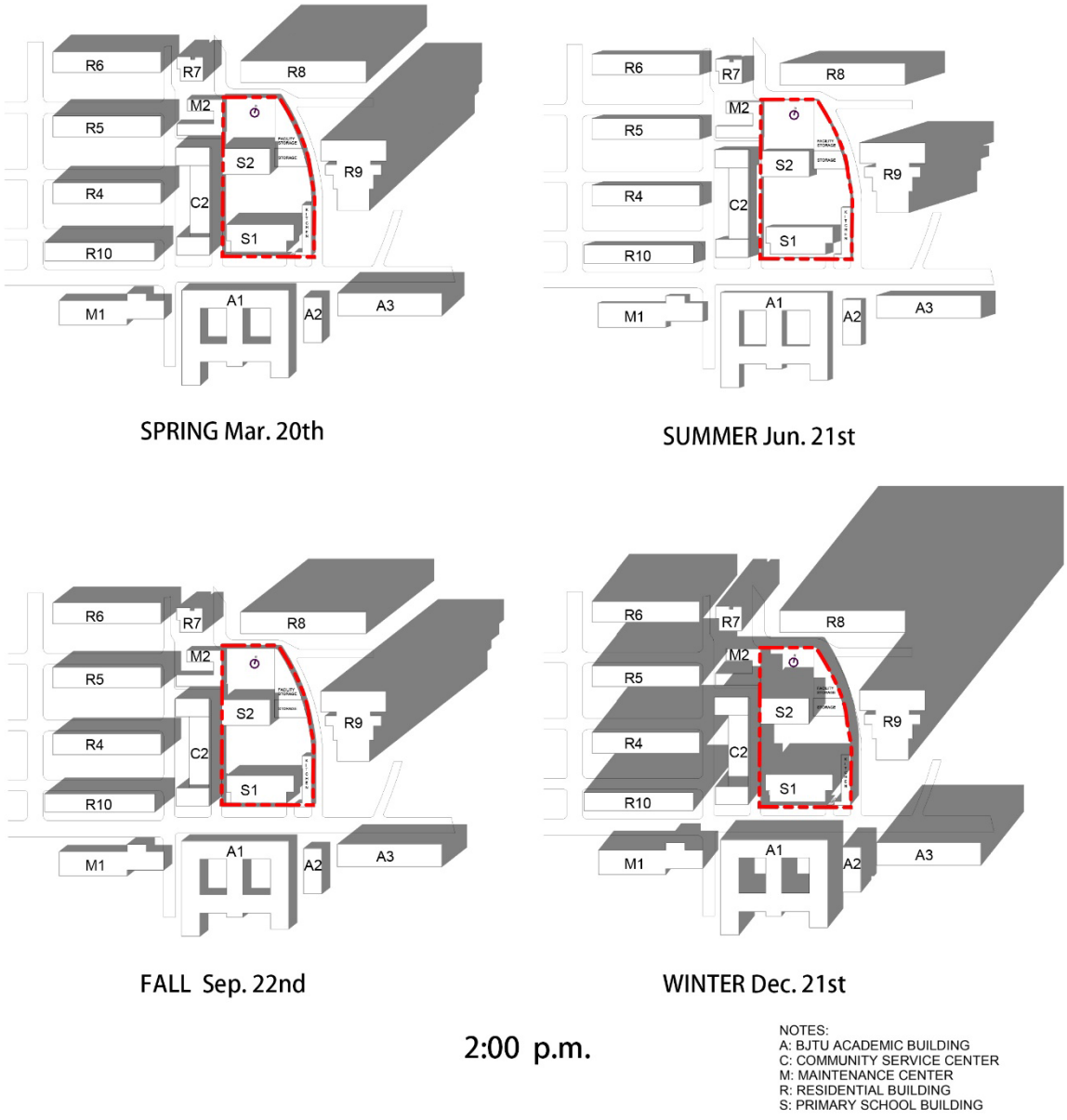

Figure 36: Shading pattern at 2:00 p.m.

The shading at 2:00 p.m. in the spring and summer is acceptable. In the fall and winter, the shading is toward the northeast. Building C2 shades the west area of campus in the

winter, making this area an unsuitable place for a playground. The shadow of on-site buildings and surrounding building occupies most of the ground space.

In conclusion, the northeast is the best place for a running track if the buildings stay in the south section of the campus.

The existing layout of the buildings blocks direct sunlight in the winter and does not take advantage of the shadows from surrounding buildings in the summer.

The existing buildings were constructed in the early 1960s. Most of the building finishes are worn, and their construction is outdated. Their heating and cooling systems and insulation need to be updated. General infrastructure needs to be replaced. The buildings are not sustainable and have high maintenance costs. Therefore, buildings S1 and S2 should be torn down. New construction will perform better in terms of both space layout and sustainability.

Empty site shading analysis:

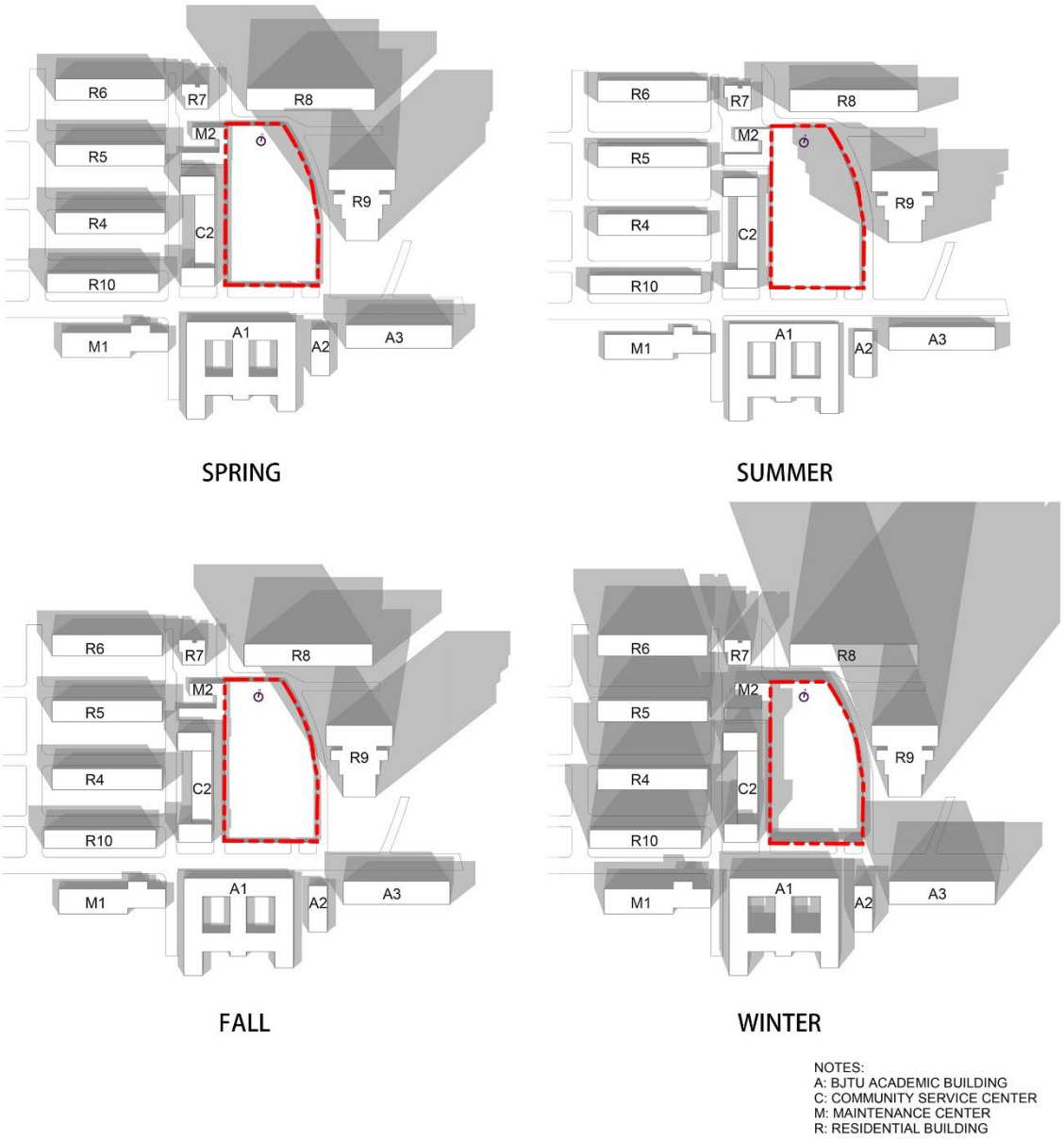

Figure 37: Shading pattern of the empty site by season

Figure 37 illustrates the shading from surrounding buildings. The shading effect in the spring and fall does not appear significant. The west portion is in shade in winter afternoons. It is best to situate the playground along the east side. The northeast is still a good place for outdoor physical activities, and the buildings will be on the west and south.

There are deciduous trees along the south road that shade the southern part of campus in the summer and do not block sunlight in the winter. Therefore, the south campus could also hold the playground. The building's shape and location will also impact the shading, but there are many ways to design it. The playground's position will be on the east side according to the building's design.

3.3 Programming

The programming is processed based on the Design Standards for Primary and Secondary Schools (GB50099-2011),[34] the Standard for Running Primary Schools and Secondary Schools in Beijing (Construction Section-Trial),[35] existing conditions, and the case study. In this step, the scale of regular classrooms, special classrooms (e.g. music classrooms, computer labs, science labs), and physical activity spaces for the elementary school are listed.

3.3.1 New Primary School Design Standards

The spaces needed for new primary school designs are based on the Design Standards for Primary and Secondary Schools (GB50099-2011) and the Standard for Running Primary

[34] "中小学设计规范 (GB50099-2011)." 北京市建筑设计研究院, 天津市建筑设计院会, 中国, 2011. ("Code for the design of school (GB50099-2011)." Beijing Institute of Architectural and Tianjin Architecture Design Institute), 2011.

[35] "北京市中小学校办学条件标准(建设部分-试行)", 北京市教育委员会,中国, 2018. ("Standard for running primary schools and secondary schools in Beijing (Construction Section-Trial)", Beijing Municipal Commission of Education, China, 2018)

Schools and Secondary Schools in Beijing (Construction Section-Trial).

Design Standards			
School Size			
Name		**Requirement**	
Primary school for GradeS 1 to 6		Two to four classes for each grade, fewer than 40 people per class.	
Total square footage in downtown		More than 14,500 square meters, could request variances.	
Land use		Rational layout. Rational use of underground space. Green spaces should not be less than 30% of total space.	
Building height		Fewer four stories.	
School entrance		At least two entrances that do not face the city's main street.	
Room Requirements			
Category	**Name**	**Number**	**Size**
Academic	Classroom	Number of Classes + 2	The first row from the blackboard is at least 2.2 meters away. The last row from the blackboard is no more than eight meters away. The height is at least three meters. Total space is at least 84 square meters.
	Teacher's office	At least one room on each floor.	Each teacher should have at least 3.5 square meters.

	Library	1	Total = Student Number x 10% x 1.5
	Science lab	2	Every two students should have at least 1.2 meters x 1.3 meters wide space. Plus, facilities spaces. Height is at least 3.1 meters. Total space is at least 87 m^2.
	Music classroom	1	Each student should have at least 2.4 m^2 space plus facilities spaces. Total space is at least 104 m^2.
	Art classroom / Calligraphy classroom	2	Each student should have at least 2.1 m^2 space plus facilities spaces. Total space is at least 96 m^2.
	Psychological counseling room	1	At least 3 meters x 4 meters wide.
	Computer lab	1	Each student should have at least 0.75 meters x 1.35 meters wide space. Height is at least 3.1 meters Total space is at least 87 m^2.
	Dance classroom	Not required but recommended.	Each student should have at least 6 m^2 space. Height is at least 4.5 meters.
Playground	Running track & Football field	1	200-meter running track including 60 meters straight runway
	Indoor playground	1 Recommended	Could also be used as an auditorium. Height is at least 4 meters
	Facility Storage	1	Not required.

Administration	Office	No requirement but needed to satisfy teaching management.	
	Clinic		
	Association office		
	Maintenance		
Others	Kitchen	1	Not required.
	Bathroom	One toilet / 13 females One toilet / 40 males and one urinal / 20 males One faucet / 40-45 people	According to the code.
	Flag-raising stage	1	

Table 1: Primary School Design Standards in Beijing

3.3.2 Existing Conditions

The academic building has three levels with two open staircases on the west and east sides. Each level consists of six classrooms, one office, and two bathrooms. The class size is around 35 to 40 students. The administration building also has three levels and two open stairs. Offices, music rooms, a computer lab, a clinic, a psychological counseling room, and a broadcast room are in this building. The additional spaces include the security guard booth, kitchen, storage, playgrounds, and exercise leader stage.

Existing Spaces		
Building	**Name**	**Number**
Academic building	Classroom (around 48 m^2)	20
	Office	3
	Bathroom	Three sets (male and female)
Administration building	Office	Eight in different sizes, three for teachers.
	Meeting room	1
	Music classroom	2
	Computer lab	1
	Library	1
	Clinic	1
	Psychological counseling room	1
	Broadcast room	1
	Bathroom	5
Playgrounds (around 22, 125 square feet)	Basketball ground	1
	100-meter running track and football field	1
	Exercise leader stage	1
Others	Security guard booth	1
	Kitchen	1
	Storage	2

	Flag-raising stage	1

Table 2: Existing spaces program

Compared with the new standard, the existing design needs to expand most of its spaces, especially the classrooms and playground. Outdoor spaces are critical in the proposed design, but the existing design does not meet the requirements. In the shading analysis, the building's location blocks the sun, which influences the quality of outdoor activity spaces. This section emphasizes that the existing buildings should be torn down to redesign the building layout running track to improve the quality of the indoor and outdoor spaces.

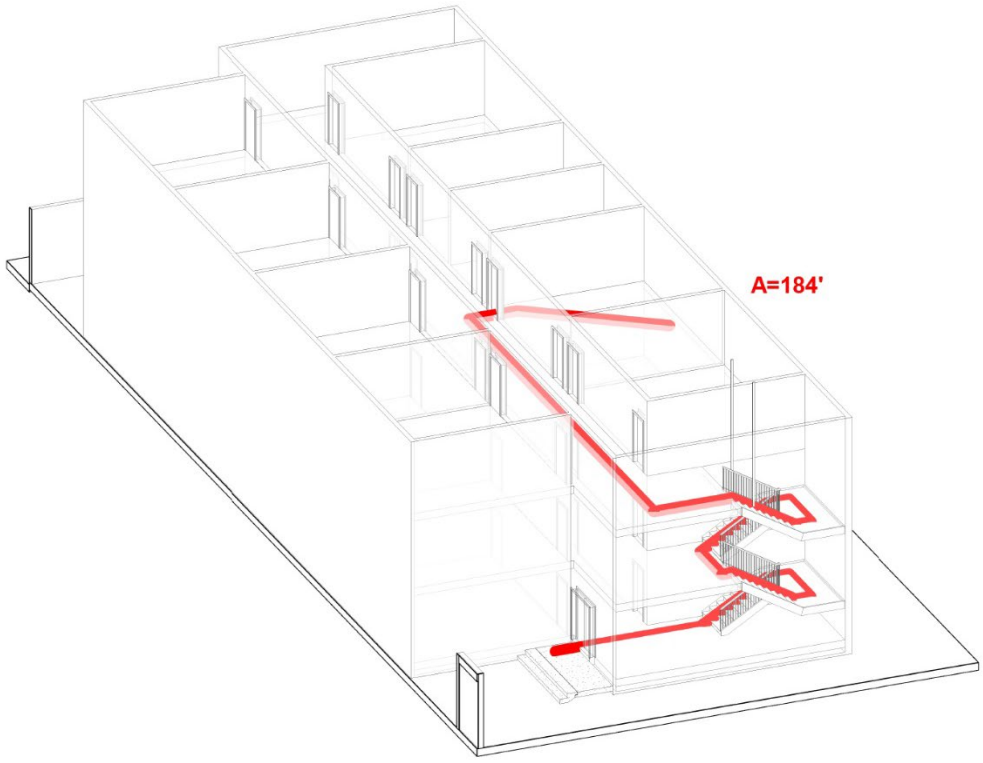

Figure 38: Existing walking path 1

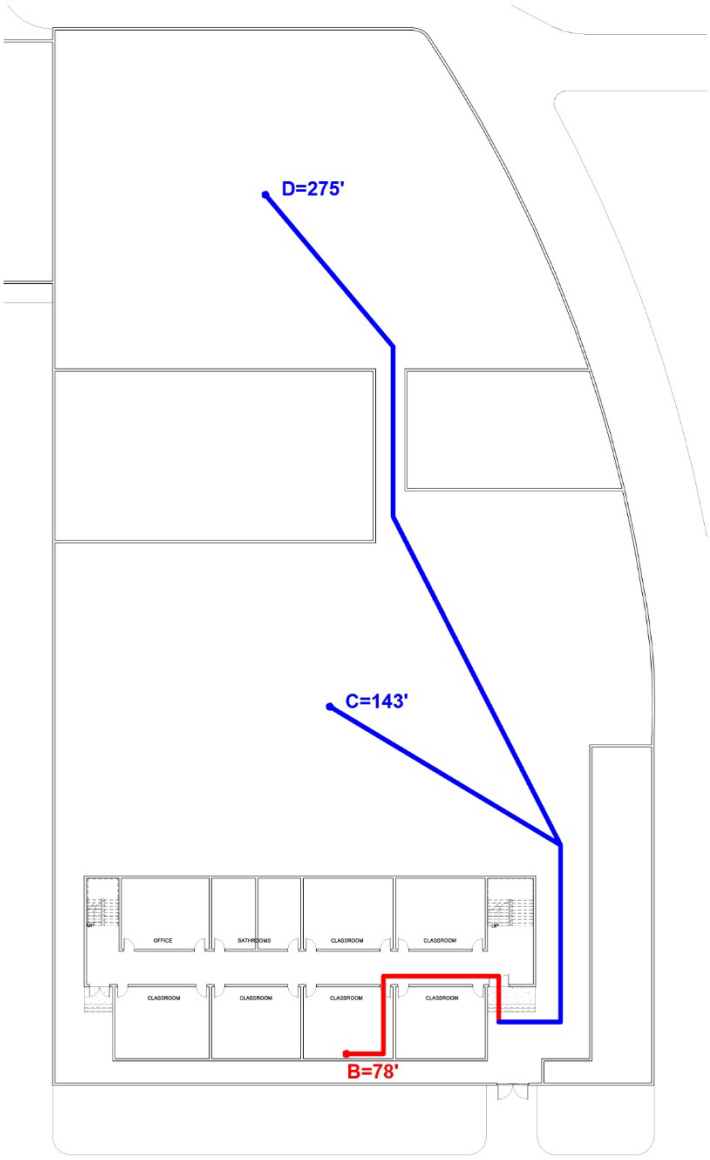

Figure 39: Existing walking path 2

The existing routes from the classrooms to the playgrounds are illustrated above. Path A is the longest indoor distance (184 feet) from the third floor. Path B is the shortest indoor distance (78 feet) from the first floor. The total distance from the classrooms to the south playground is 327 feet and 221 feet, and 459 feet and 353 feet to the northern playground. The average route length is 340 feet. By rearranging the spaces, the walking paths will be shorter.

3.3.3 Programming for a New Design

By synthesizing the existing conditions and standards, the programming for the new primary school design is as follows.

Design Goals:

To increase the opportunity for physical activity for primary school students in urban China.

1) Increase the number and size of outdoor spaces. Establish activity spaces at least every two floors.
2) Improve the quality of indoor and outdoor spaces.
3) Minimize the influence on the existing context.
4) Be socially and environmentally sustainable.

Requirements:

1) The design must obey the regulations.
2) The new design should keep the number of existing spaces as the minimum requirement.
3) New classrooms can be added as the minimum requirement is met.

Spatial Needs:

The existing class comprises around 35 to 40 students. The new standard requires each

class to have fewer than 40 students. For this program, the class size is assumed to be 36. The existing playgrounds are 22,125 square feet in total. The required space for a standard 200-meter running track is 53,819 square feet, more than the existing space. The new playground will request a variance. In this design, the playground could be a 150-meter running track with 60 meters of straight track which is 27,053 square feet in total. The requirement for the classroom size is not applicable for this small site, which also needs to request a variance.

The program details are listed in Table 4. Other rooms will be sized according to the number of student and standards.

Spatial Needs			
School Size:	Classes: 18 Students: 36 people per class, 648 people in total. Teachers: 40 Site Area: 45,757 ft^2 Building height: Four stories above ground and one story underground.		
Category	**Name**	**Number**	**Size (Single)**
Academic	Classroom	20	22 ft x 29 ft, details in Figure 38
	Teacher's office	One on each academic level.	200 ft^2 for five teachers on each floor.
	Music classroom/Dance room	2	1,120 ft^2
	Science lab	1	800 ft^2

	Computer lab	1	936 ft^2
	Art classroom	2	1,033 ft^2
	Library	1	Utilize the small area on each floor.
Playground	150-meter running track & football field	1	27,053 ft^2
	Exercise leader stage	1	215 ft^2
	Open spaces	2	At least 1,000 ft^2
	Indoor playground/Recreation center	1	2,000 ft^2
	Facility storage	1	900 ft^2
Administration	Office for administration	5	N/A Different sizes
	Meeting room	1	350 ft^2
	Psychological counseling room	1	200 ft^2
	Clinic	1	100 ft^2
	Maintenance office	1	100 ft^2
Others	Kitchen	1	1,500 ft^2
	Bathroom	Install on each level.	According to the number of occupants on each floor.
	Flag-raising stage	1	130 ft^2
	Storage (Archives)	1	300 ft^2

	Security guard booth	One at gate	25 ft^2

Note:

1. All areas are approximate, except the detailed notes.

Table 3: Spatial needs program

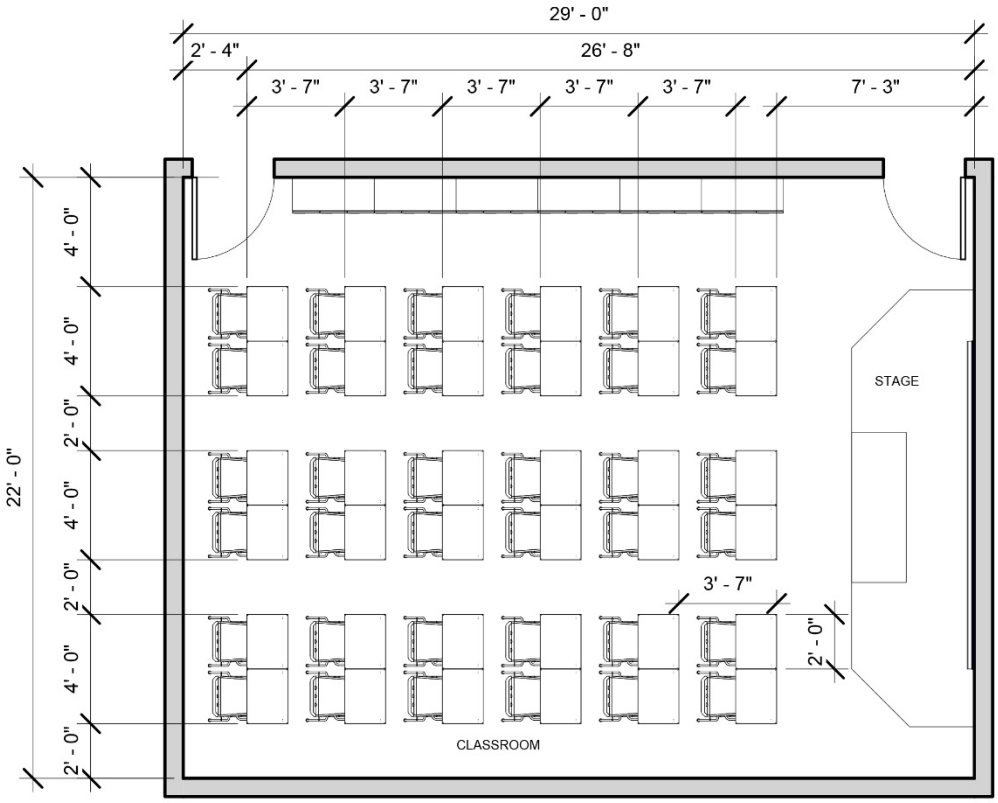

Figure 40: Size and layout of classroom

All regular classrooms will be sized to meet the minimum requirements: “The first row from the blackboard is at least 2.2 meters. The last row from the blackboard is no more than 8 meters. The height is at least 3 meters.” The layout of the classroom is in the figure 40.

3.4 Design Proposal

The design synthesizes all the information above. The proposal is divided into two parts: the site design, and the building design. Sketches and massing models deliver it to show

the design development. Revit is the primary 3D model software. SketchUp is used to assist the space design and analysis. The final delivery format requires other digital software to refine it.

3.4.1 Building's Location on the Site

According to the site analysis, the running track is best placed on the east side. To achieve the goal of promoting exercise, physical activity spaces are the priority. The most suitable spaces for the building are located on the side of the campus. There are two site plans for the layout of the buildings. To maximize the space, the buildings are all in basic four-story L shapes. Plan A places the buildings on the south side. Plan B places the buildings on the north side. One of the plans will be developed following the evaluation of the spaces.

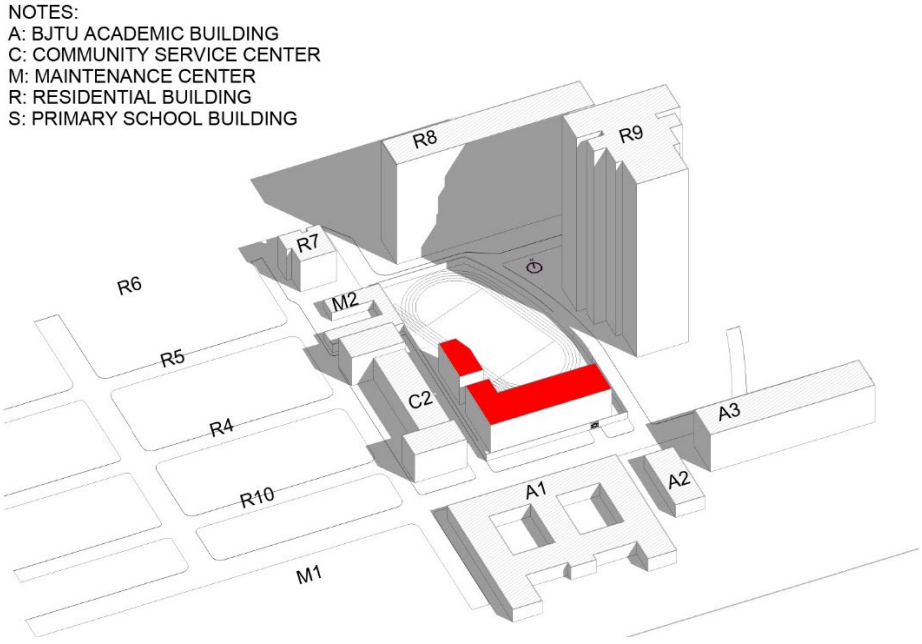

Figure 41: Plan A site 3D view

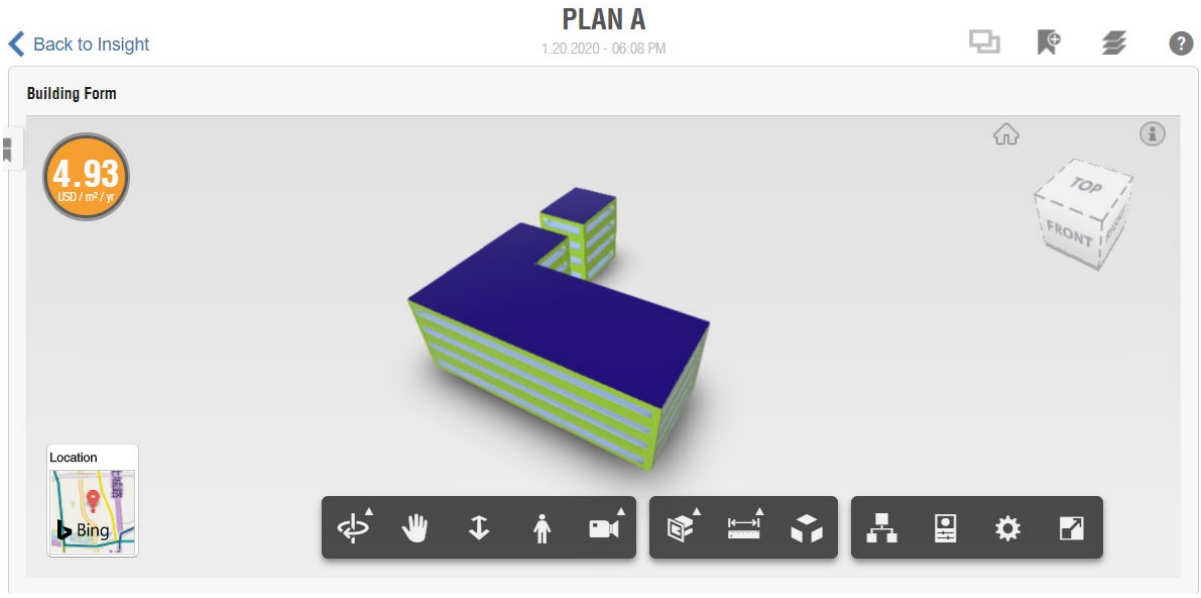

Figure 42: Plan A building performance

Plan A Evaluation			
Pros (+)	Weight	Cons (-)	Weight
Good street view. Aligned with the other buildings on the street.	3	Insufficient direct sunlight for the playground in the winter.	4
Buildings close to the gate.	2	Noise from the street.	3
Partially shaded in the summer.	4	The playground close to the buildings is shaded in winter.	5
The playground close to the buildings is shaded in summer.	5	No block from the cold wind.	3
		Building performance	1
Total	+14	Total	-16
Result			**-2**
Note: The weight is measured from 1 to 5, with 5 being most important.			

Table 4: Plan A evaluation

Plan A's evaluation produced a negative grade. Although the street view is good, the playground does not function sufficiently to achieve the goal; there is too much shade covering the outdoor space in the winter. Students exercising in the winter cannot receive sufficient sunlight. The area close to the buildings, where most students will stay for the short break, is in shadow in the winter and exposed in the summer.

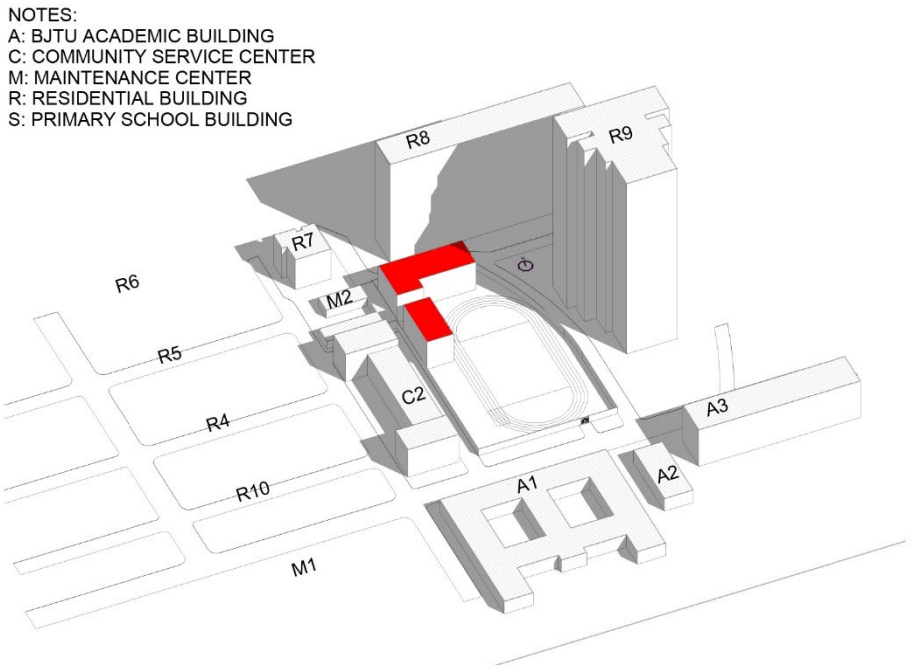

Figure 43: Plan B site 3D view

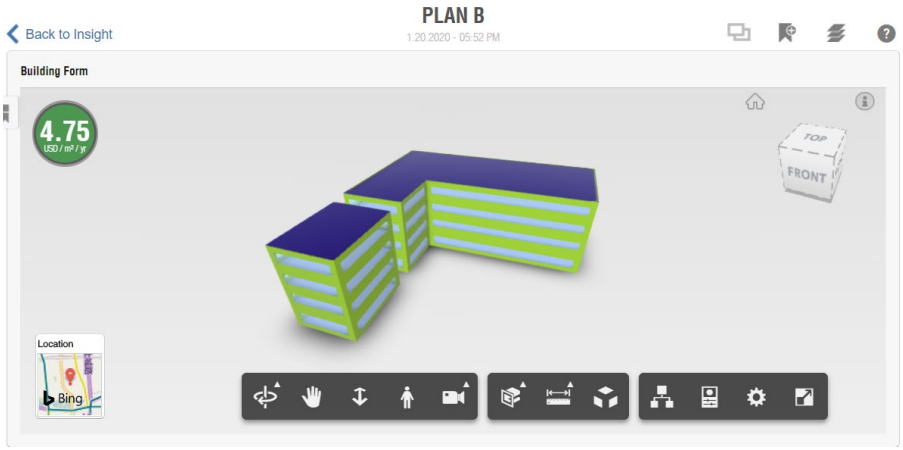

Figure 44: Plan B building performance

Plan B Evaluation			
Pros (+)	Weight	Cons (-)	Weight
A buffer between academic buildings and the street.	3	Entrance far from the buildings	4
Blocks cold wind in winter, proper ventilation in summer.	3	Small flexible space for the building.	3
Sufficient direct sunlight for the playground in the winter.	4		5
Partially shaded in the summer.	4		3
The playground close to the buildings is warm in winter.	5		
Building performance	1		
Total	+20	Total	-15
Result			**+5**
Note: The weight is measured from 1 to 5, with 5 being most important.			

Table 5: Plan B evaluation

Plan B's evaluation, with a score of +5, is better than Plan A's result. The outdoor space performs well in the summer and winter. The space takes advantage of the shade from surrounding buildings in the summer. In the winter, the playground close to the buildings receives direct sunlight across a large area. The site is responsive to the wind, blocking the cold wind for the playground in winter and allowing the wind in summer. The building performance of Plan B is better than Plan A and is below the ARCH 2030 benchmark.

Plan B is developed in the next step.

3.4.2 Building Design

Design Process:

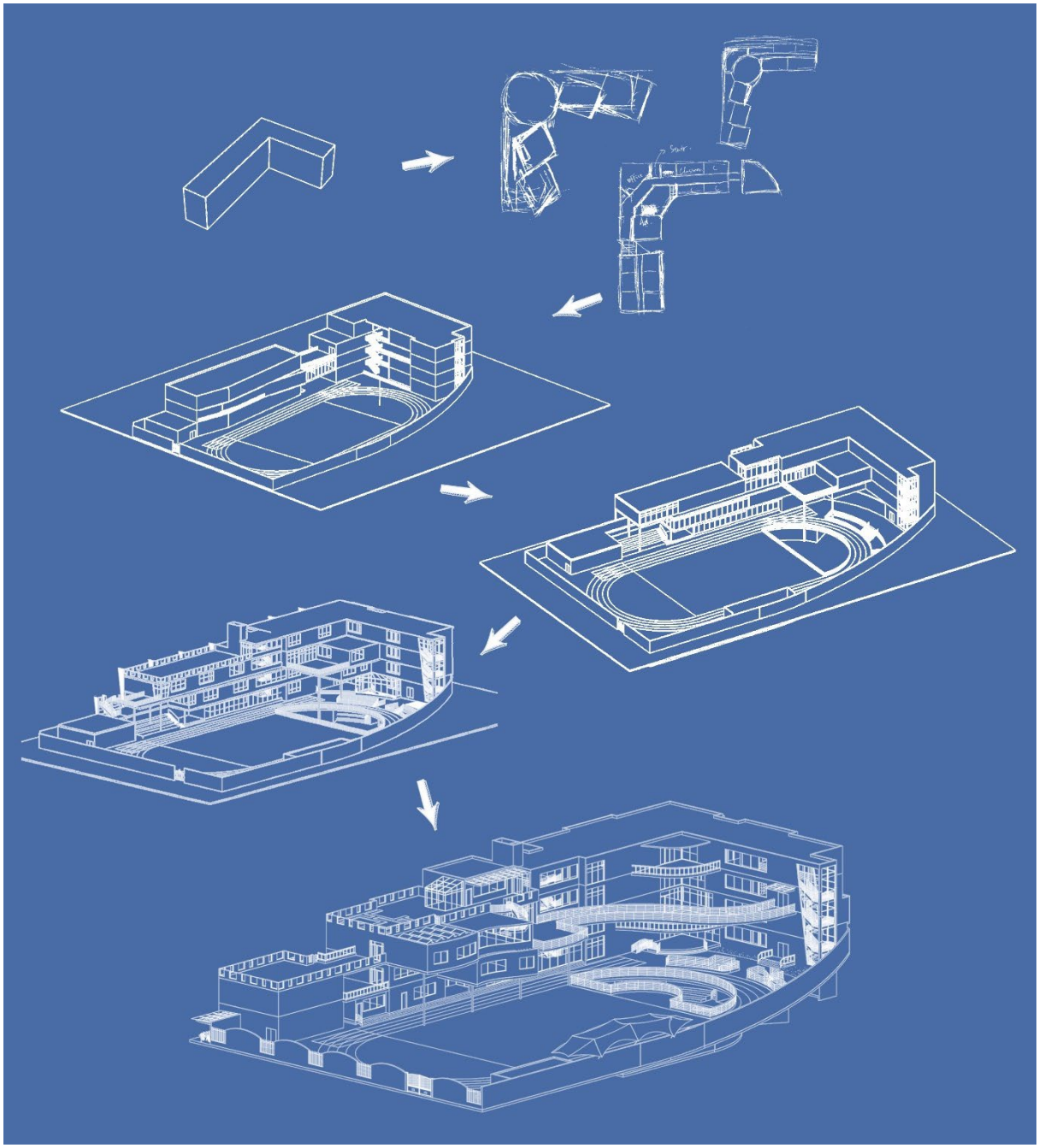

Figure 45: Design process

According to the previous analysis, the buildings will be located in the northwest corner of the campus. Starting with the L-shaped buildings to maximize the ground outdoor

space, different types of outdoor areas are embedded into the building.

The first concept is two building masses connected by indoor and outdoor bridges. This design is intended to separate the regular classrooms from special classrooms for music, art, and science. In addition to the outdoor bridge on the third floor, there are another two outdoor areas for physical activity on the second and third floors close to the outdoor stairs. However, the outdoor areas are small and far away from the classroom, which does not improve the quality of access to the outdoor spaces.

The second concept develops the basement to move the music classroom out of the main area. This design decreases the size of the building, but also eliminates the outdoor spaces.

The third concept is based on the second concept and increased outdoor spaces. The interior layout situates classrooms on the north side, which reduces interactions with outdoor spaces; there are only uncovered physical activity spaces that do not meet the goal of having multiple types of spaces.

The final concept redesigns the interior layout, increases the type of physical activity spaces, and refines the quality of the spaces. This design achieves the goals of the design purpose. The layout is illustrated below.

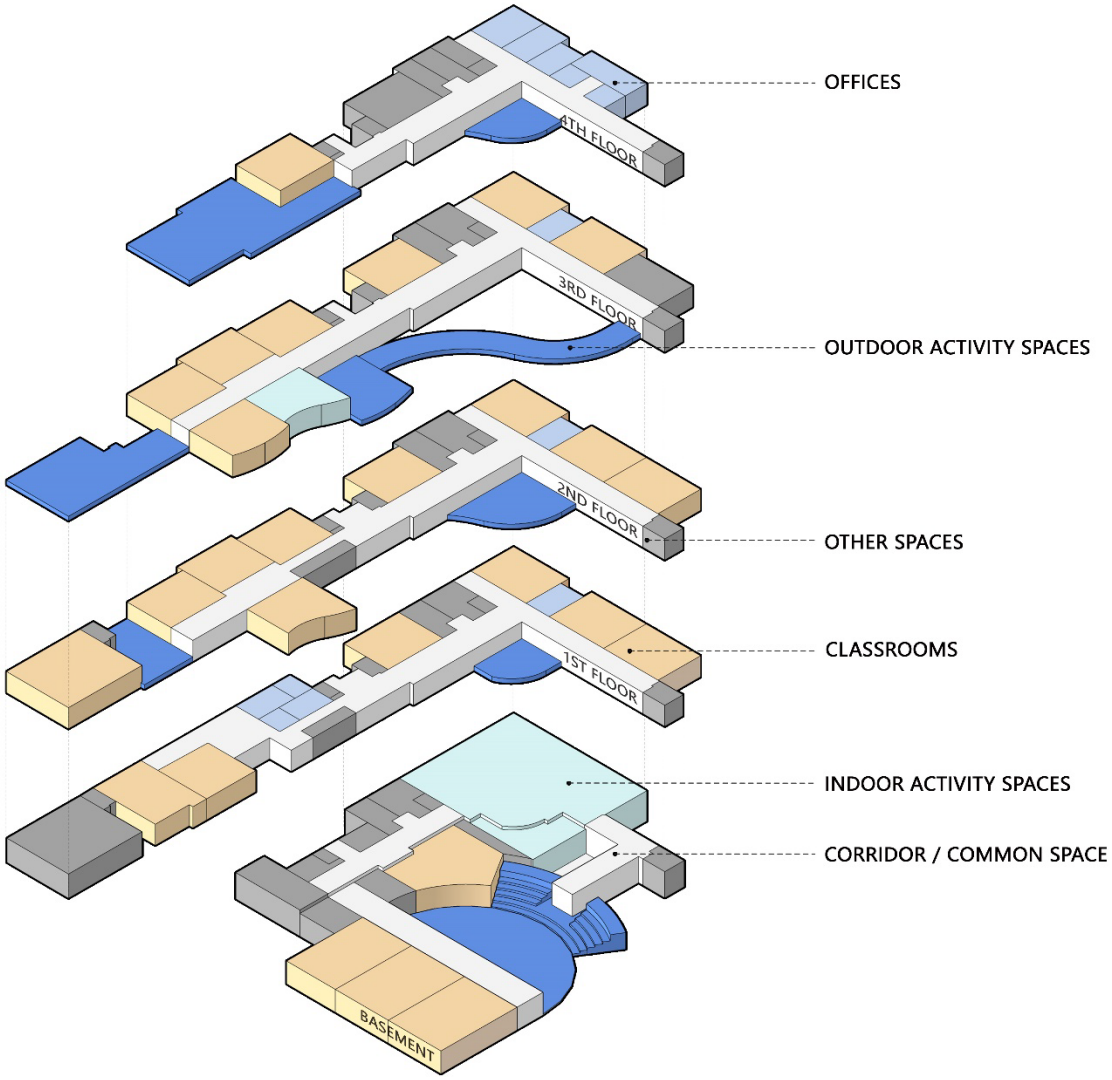

Figure 46: Building massing

The building is designed to be four levels above ground and one level below ground. Figure 46 illustrates the general spaces in six categories: offices, classrooms, indoor and outdoor activity spaces, corridor/common spaces, and other spaces, which include a meeting room, reading area, staircases, an elevator, bathrooms, janitor rooms, and storage.

There are physical activity spaces on each floor. As the level increases, so does the area of outdoor space. The third floor and basement each have an indoor multi-use activity space. Except for one classroom on the fourth floor, the other classrooms are on the lower

levels. The basement provides different indoor and outdoor access, and a sunken square.

Site Plan:

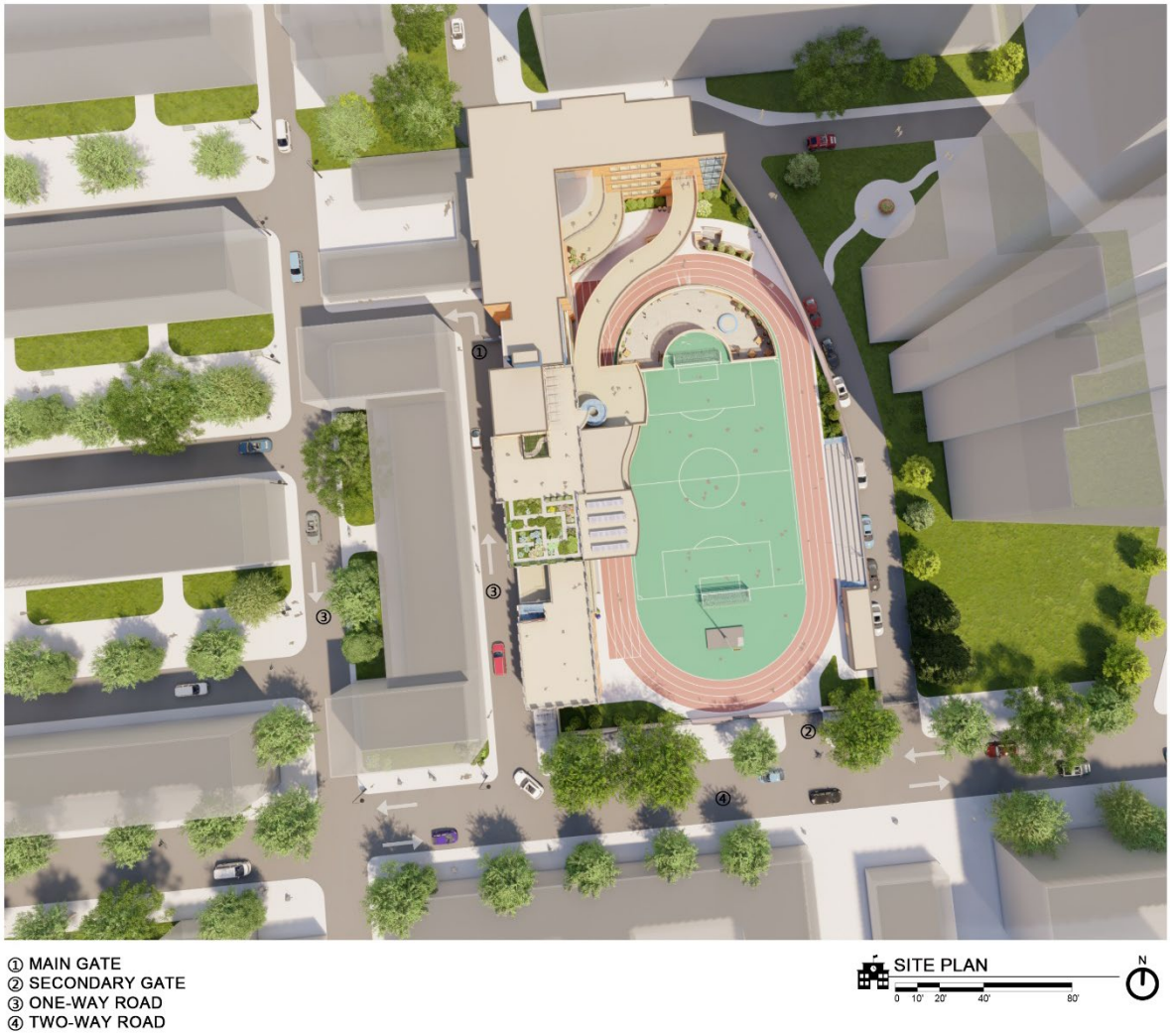

Figure 47: Site plan

Based on the final concept, the site plan illustrates the campus's connection with its surroundings. The new design does not change the property lines. The existing gate will remain as the second gate. The school's main gate will be on the western road close to the academic building, will have less circulation, and could relieve peak-hour traffic. It is

recommended to change this road to one-way for safety considerations. The fence wall on the south side will be replaced with the new configuration in which the fence inserts into the wall, which enhances the interaction between the campus and its neighbors. The new design will not affect the roads on the northern and eastern sides.

Floor Plans:

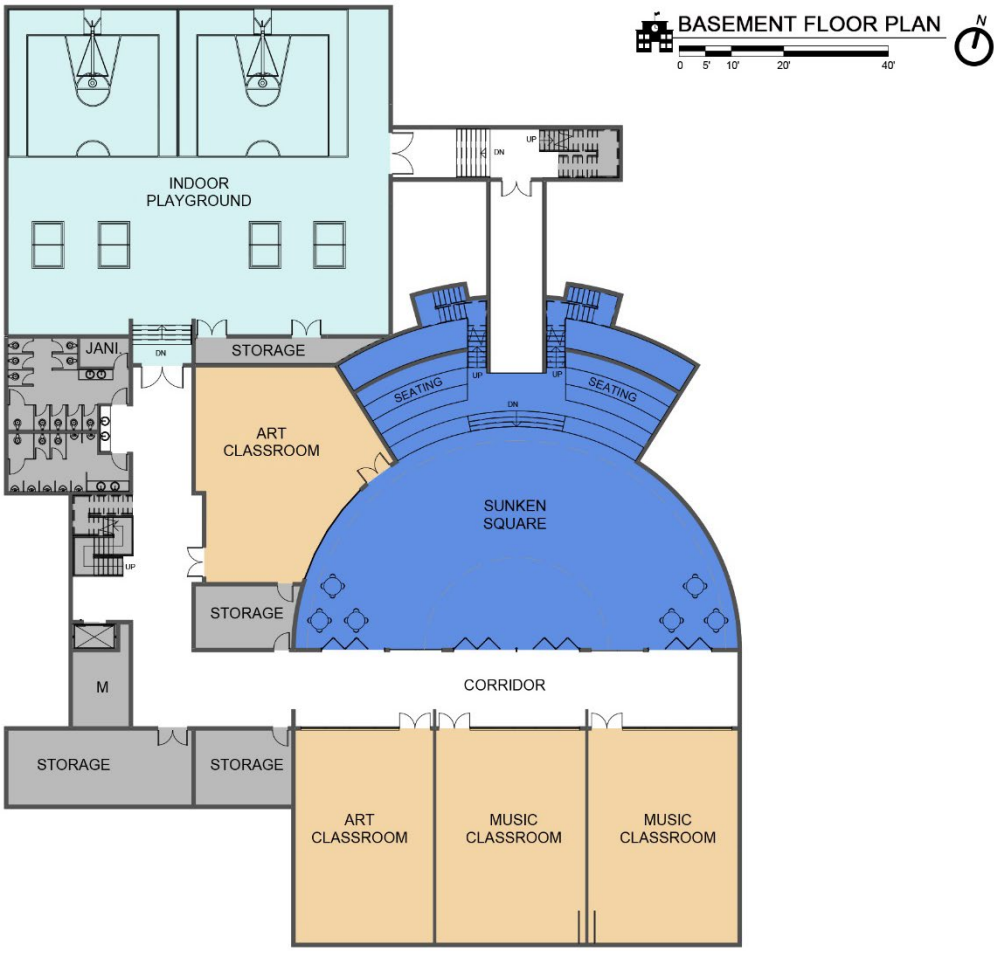

Figure 48: Basement floor plan

The basement includes two art classrooms, two music classrooms, a large indoor recreation space, a mechanical room, some storage, and a sunken outdoor square. The indoor

playground has some movable sport facilities, which allow this indoor area to function as an auditorium. The isolation between the music classrooms is a movable insulated door such that it can merge two rooms into a large space for music or dance. The wider corridor in front of the music classrooms is also a play area. During the summer, the Nanawall can be opened to eliminate the barrier to the outdoors. The sunken square takes the space of the running track's semicircle and provides an open space for students who have classes in the basement. The square can be used as an event space for a small concert, chorus performance or speeches. The stepped seating area coordinates with the stairs to the north.

Figure 49: Sunken square rendering

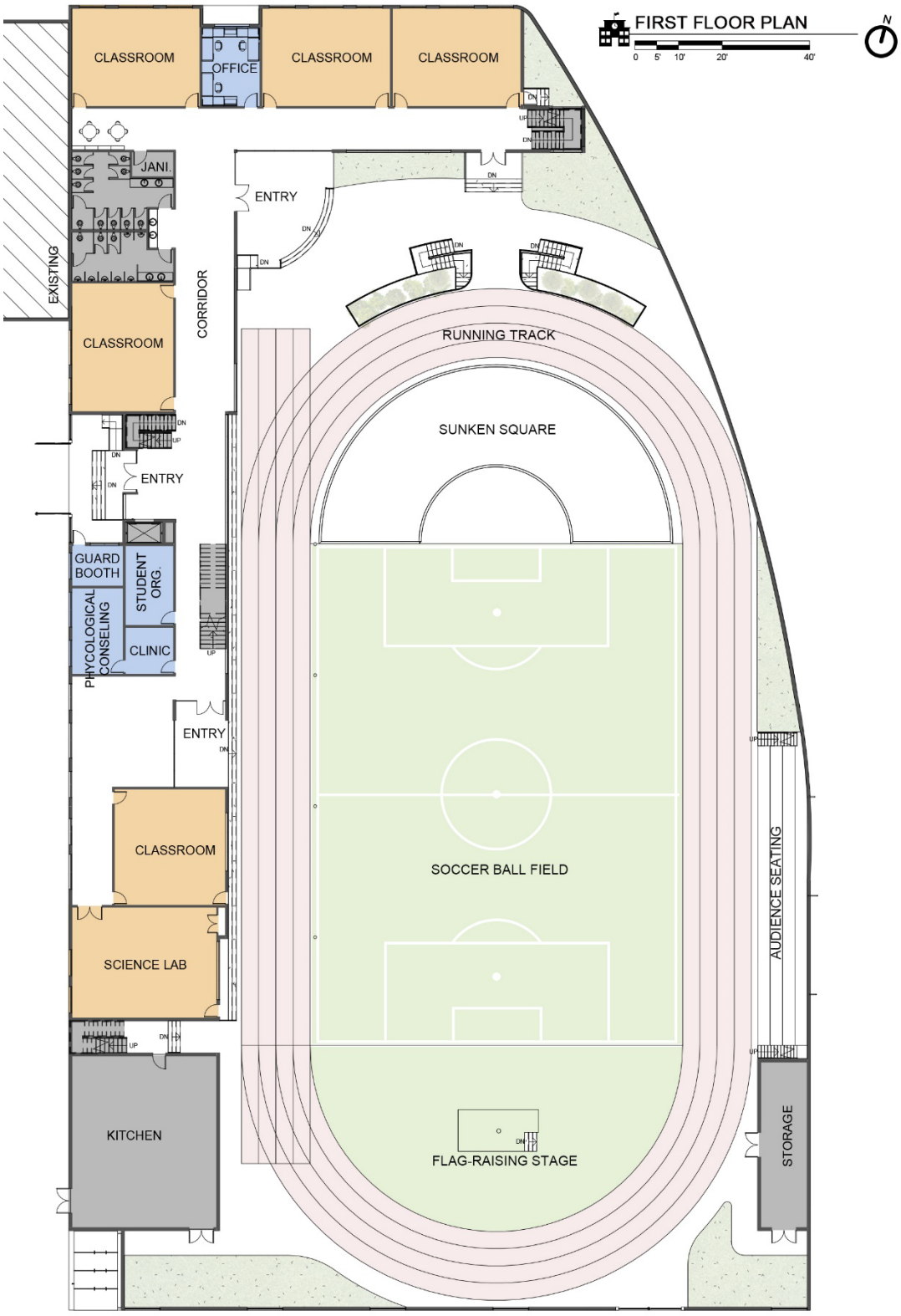

Figure 50: Ground/first floor plan

The ground is 1 foot 8 inches lower than the first level. The school's main entrance is on the west side facing the entry to the building. A guard booth is close to the entrance to maintain safety. Another gate is on the south side of campus and is normally closed.

Figure 51: Ground view rendering

A 150-meter running track with a soccer field occupies most of the space on the ground. The soccer field will be painted to become a multi-use outdoor space. Students can enter this area via four access points, three on the first floor and one in the basement. On the east side, there is an audience seating stage and fitness equipment storage. The level change means that the stairs in front of the buildings extend to become a seating stage where students can put personal belongings or take a rest. The kitchen in the southwest corner does not influence the school routine. The leader stage could be on the north movable soccer goal's location. The flag-raising stage is in the center of the southern semicircle.

The first floor has five regular classrooms, a science lab, a faculty office, a student organization office, and a clinic with a psychological counseling room. The elevator is located at the main entrance. Stairs are in different locations to meet the large demand of students. The straight staircase in the center of the building is only to the second floor to bring students to the ground-floor play area. The science lab on this floor has access to the outside for outdoor experiments, and the room's double-sided windows provide good ventilation. There is another science lab on the fourth floor that could be used for different experiments.

Open spaces at the north end of each floor become small areas where students can read books, relax, or converse. These reading areas and bathrooms are located at similar locations on each floor. The corridor walls facing the playground on each floor are mostly clear so that students can always see the outdoors. This factor could influence students to go outdoors to play with their friends.

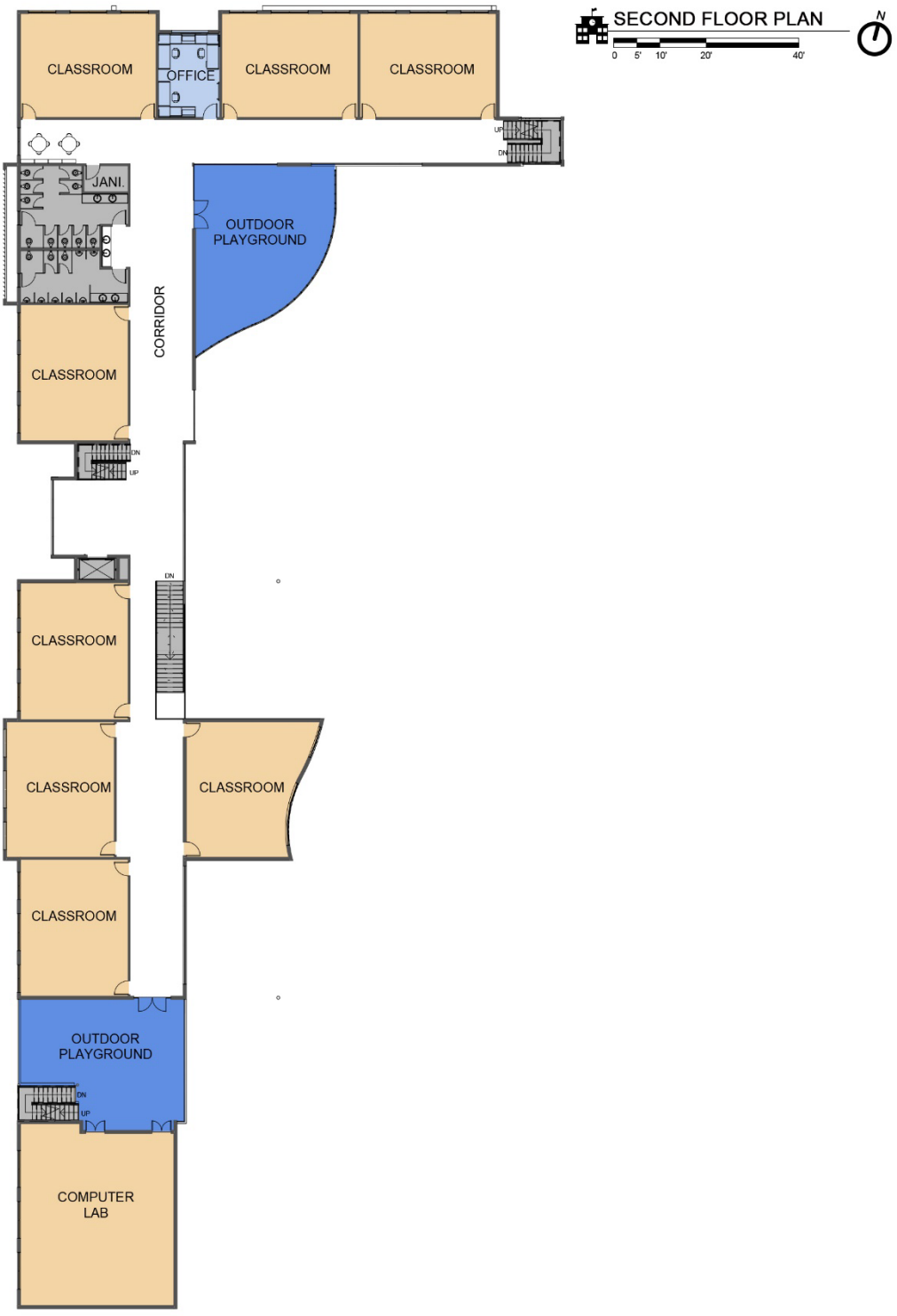

Figure 52: Second floor plan

Figure 53: Second-floor outdoor winter rendering

The second floor has the most classrooms. There are eight regular classrooms and a computer lab that is near to the outdoor playground. Students going to or returning from the computer lab could play in this playground. Another outdoor playground is in the inner corner. The second floor is a lower level from which students can go to the ground quickly, and an additional staircase at the center encourages students to go the physical activity area.

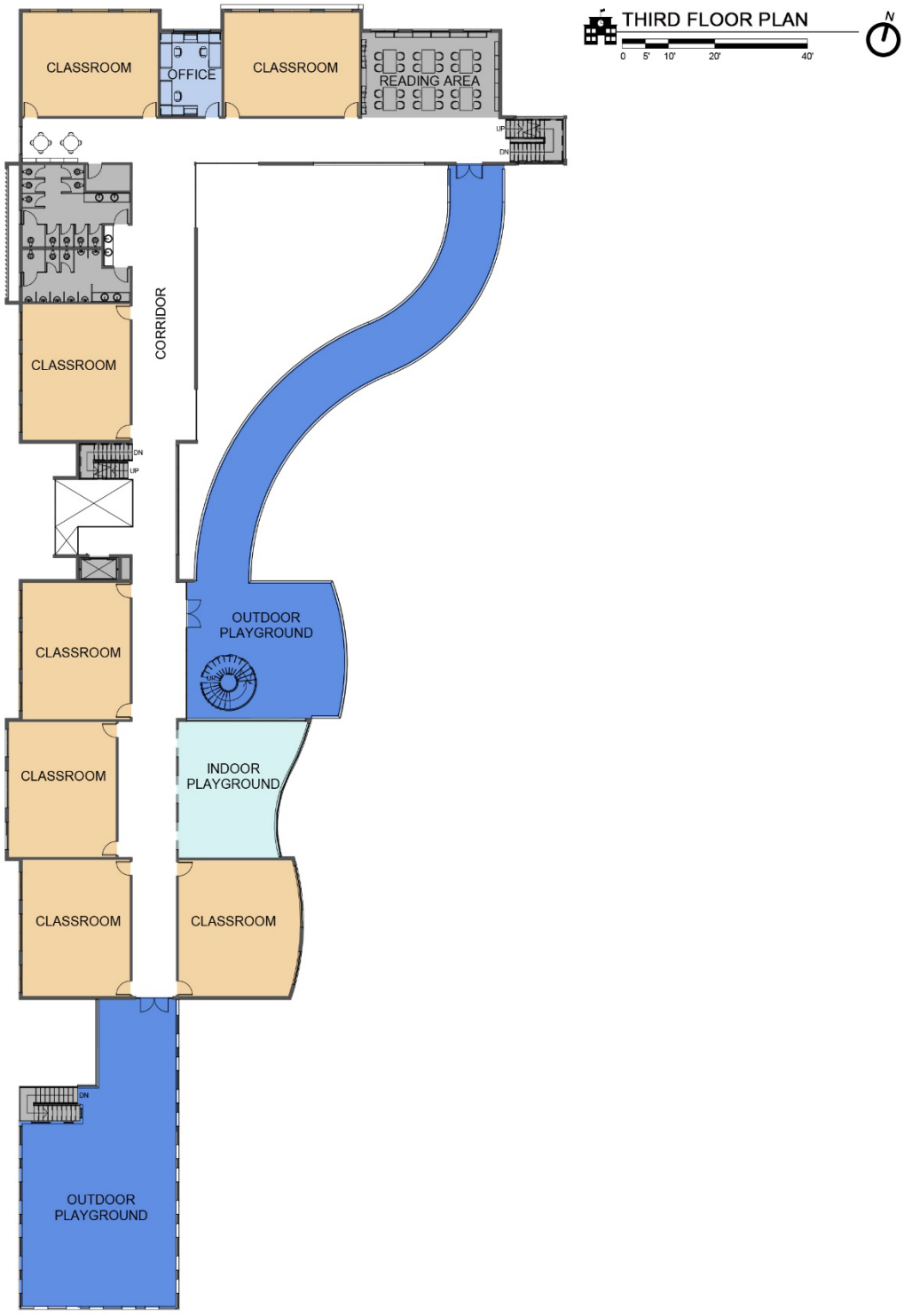

Figure 54: Third floor plan

The third floor includes six regular classrooms, an office, a large reading area, two outdoor playgrounds, and an indoor playground. There is an outdoor bridge connecting the center of the building to the north side. Students from the southern building can access the reading area through this outdoors bridge. They can see different activities on this bridge that they may want to participate in. The indoor playground is next to the central outdoor playground to promote interaction between the inside and outside. The clear glass wall between the outdoor playground and the corridor encourages students to go outside while passing by.

Figure 55: After-rain rendering

Figure 56: Fourth floor plan

The fourth floor has only one classroom: the science lab. The main function of this floor is administration, with offices on the north side of the building. The northeast is an opening where teachers can see the lower level's reading area. Staff also need fresh air, so they can access the nearest outdoor area from this floor. The science lab is outdoors, where students can conduct natural experiments, such as plant research and wind studies.

Figure 57: Roof rendering

The roof garden creates a plant maze, which could be a good place for scavenger hunts. Students can learn and play there. The garden is also a potential place for rainwater-harvesting systems. There is a circular staircase that connects to the third-floor play area. Students on the third floor can access the fourth-floor outdoor recreation area using this staircase. Students are not allowed to access the solar panel area, but they can see it through a glass fence. The door to the solar panel area is closed at all times unless regular maintenance is taking place.

Building Sections:

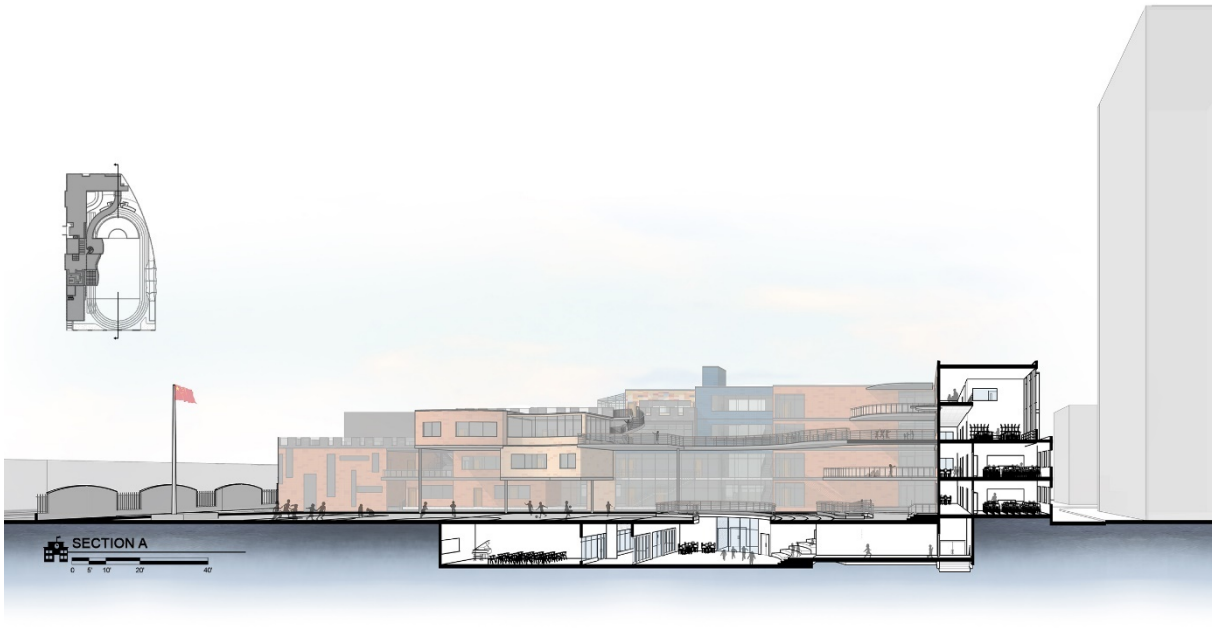

Figure 58: Building Section A

Figure 59: Building Section B

Figures 58 and 59 are the building sections that display the levels change for different spaces. Section A displays the eastern building section and sunken square activities. Section B highlights the center stair connecting the first floor and second floor, and the view of the long western corridor.

Color Research:

Figure 60: Surrounding buildings

Figure 61: Surrounding building colors extraction

The building's color should be in harmony with the existing context and educational environment. Figure 61 displays the building colors around the site. By pixelating the photos without the sky, three primary colors were extracted from the surrounding buildings. The

colors approximate to yellow, peach puff, and deep tangerine.

Psychologically, students in primary school prefer warm, bright colors, such as red, orange, or yellow.[36] These colors stimulate brain activity, which is why they are encouraged for teaching new concepts but inappropriate for working quietly and reading. For the reading area, cool colors such as blue, violet, or green help to calm and relax.[37] The brightness and saturation of the colors also influence student behavior.

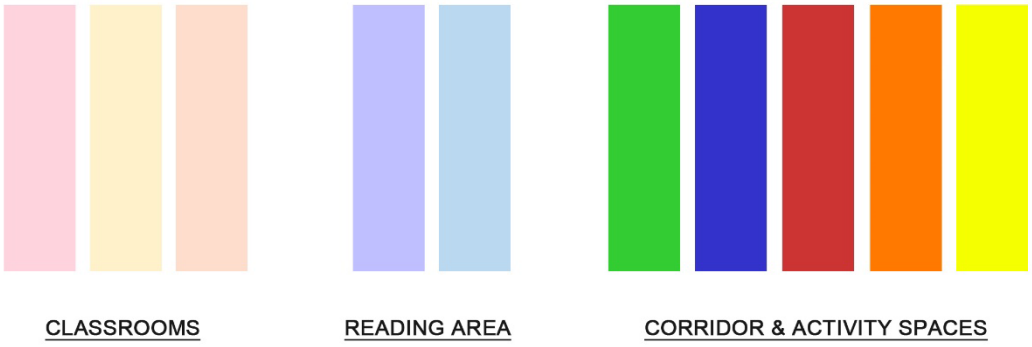

Figure 62: Proposed color palettes

For the primary school design in this thesis, different colors are used to correspond to different spaces. In the classroom, soft, warm colors are used to promote creativity and productivity. The study and reading areas are better for soft, cool colors. The hallway, indoor activity spaces, and building exterior finishes will use bright colors to be energetic and restful.

[36] Jaap le Poole, "Psychology of Colour in the Educational Environment - Color Objects," Color Objects, accessed March 22, 2020, http://www.colorobjects.com/en/color-columns/the-colour-real/item/357-psychology-of-colour-in-the-educational-environment.html.
[37] Saul Wagner, "The Power of Color in Classroom Design," Hertz Furniture, accessed March 23, 2020, https://www.hertzfurniture.com/buying-guide/classroom-design/classroom-colors.html.

Façade Material:

Figure 63: Rain screen building case[38]

The school building will use different colors for its façade, so the exterior finish needs to be colored easily. The rain screen system is an appropriate finish for the color pattern for the building exterior. Figure 64 illustrates the colored rendering of the entire campus.

Figure 64: Campus rendering

[38] Steven Chester, "Exploring Color in Architecture," *ARCHITRENDS-News from the Built Environment* (blog), March 2019, https://blog.stocorp.com/2019/03/exploring-color-in-architecture/.

4. Analysis and Results

This chapter compares the proposed school design with the previous design. Furthermore, the chapter analyzes the changes regarding space and access to physical activity. The results prove that this thesis successfully solves the inadequate physical activity space issue. The daylighting analysis evaluates the light levels throughout the entire building.

4.1 Space Improvements

The new design makes some changes to the existing spaces. There are increases and decreases to floor areas on each floor, and the new layouts will change student behavior in the school.

4.1.1 Interior Spaces

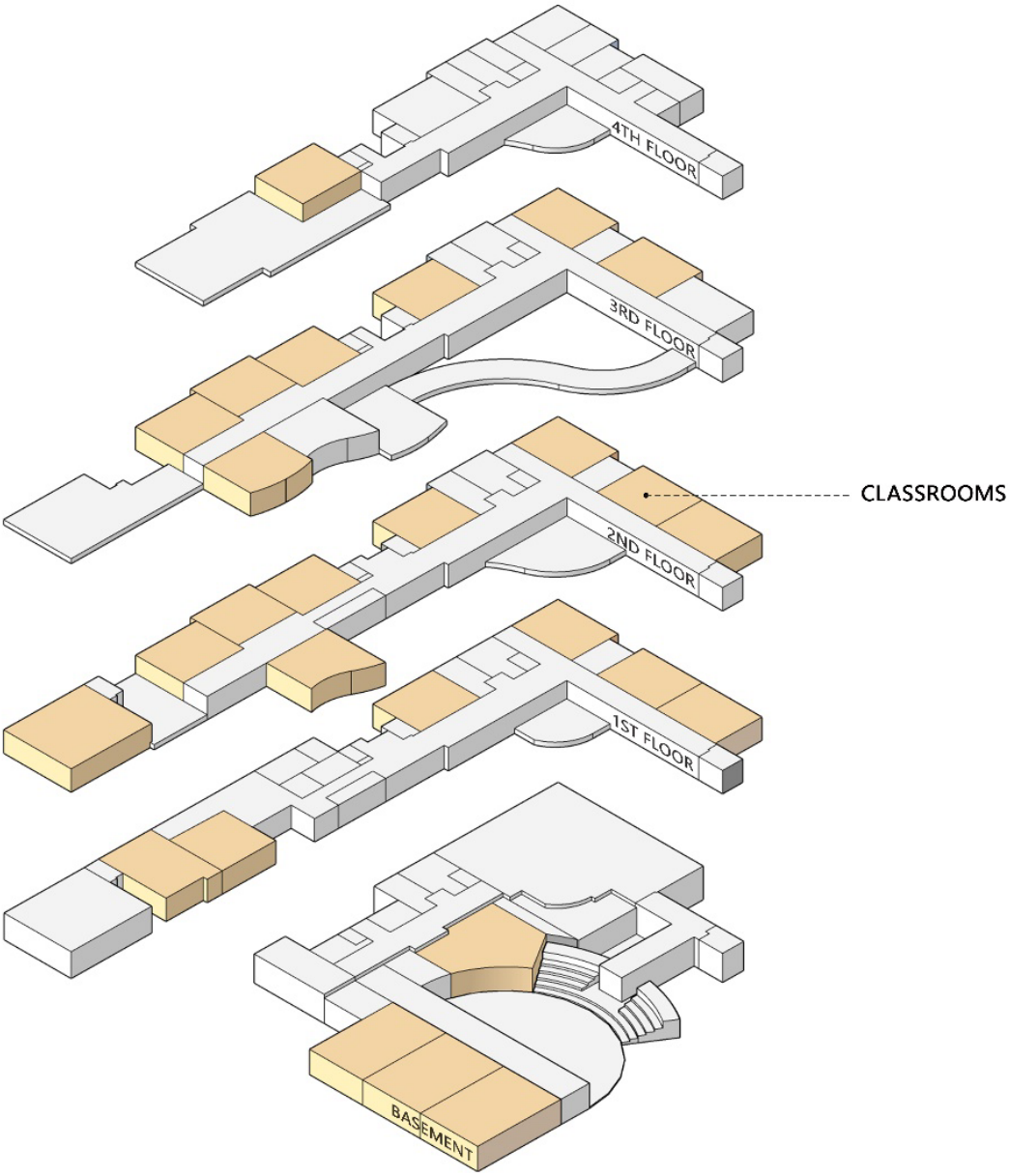

Figure 65: Classrooms on each level

Regular classrooms are on the first, second, and third floors, which are not too far from the ground, reducing the walking distance. The special classrooms are on the top level and in the basement, where students spend less time but walk long distances to reach the classrooms. However, walking is also a mode of exercise.

	Existing(ft^2)	Proposed (ft^2)	Changes (%)
Underground	N/A	4,588	N/A
First Floor/Ground	4,312	4,189	-3%
Second Floor	3,698	6,697	+81%
Third Floor	4,112	4,819	+17%
Fourth Floor	N/A	680	N/A
Total	**12,122**	**20,973**	**+73%**

Table 6: Comparison of classroom areas

The classroom areas are increased by 73%. The normal classroom size will increase from 514 square feet to 638 square feet, making them more flexible and comfortable. The two new art classrooms and two science labs will help students to master more skills and to explore the world.

There is also one large reading area and four small ones on each floor to provide students with quiet spaces. These areas are isolated from the energetic physical activity spaces. Children need not only a healthy body, but also a healthy mind.

4.1.2 Physical Activity Spaces

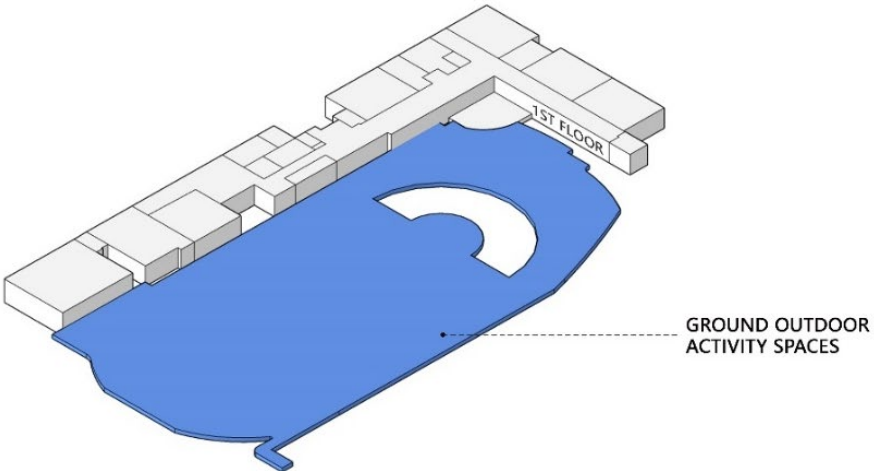

Figure 66: Ground-floor activity space

The ground-level outdoor space is 26,493 square feet. The new ground space consists of a 150-meter running track, a soccer field, and some free spaces. This area can hold large events, assembled physical activities, PE classes, and recess. There are multiple access points to this space from different levels, which encourages students to go outside.

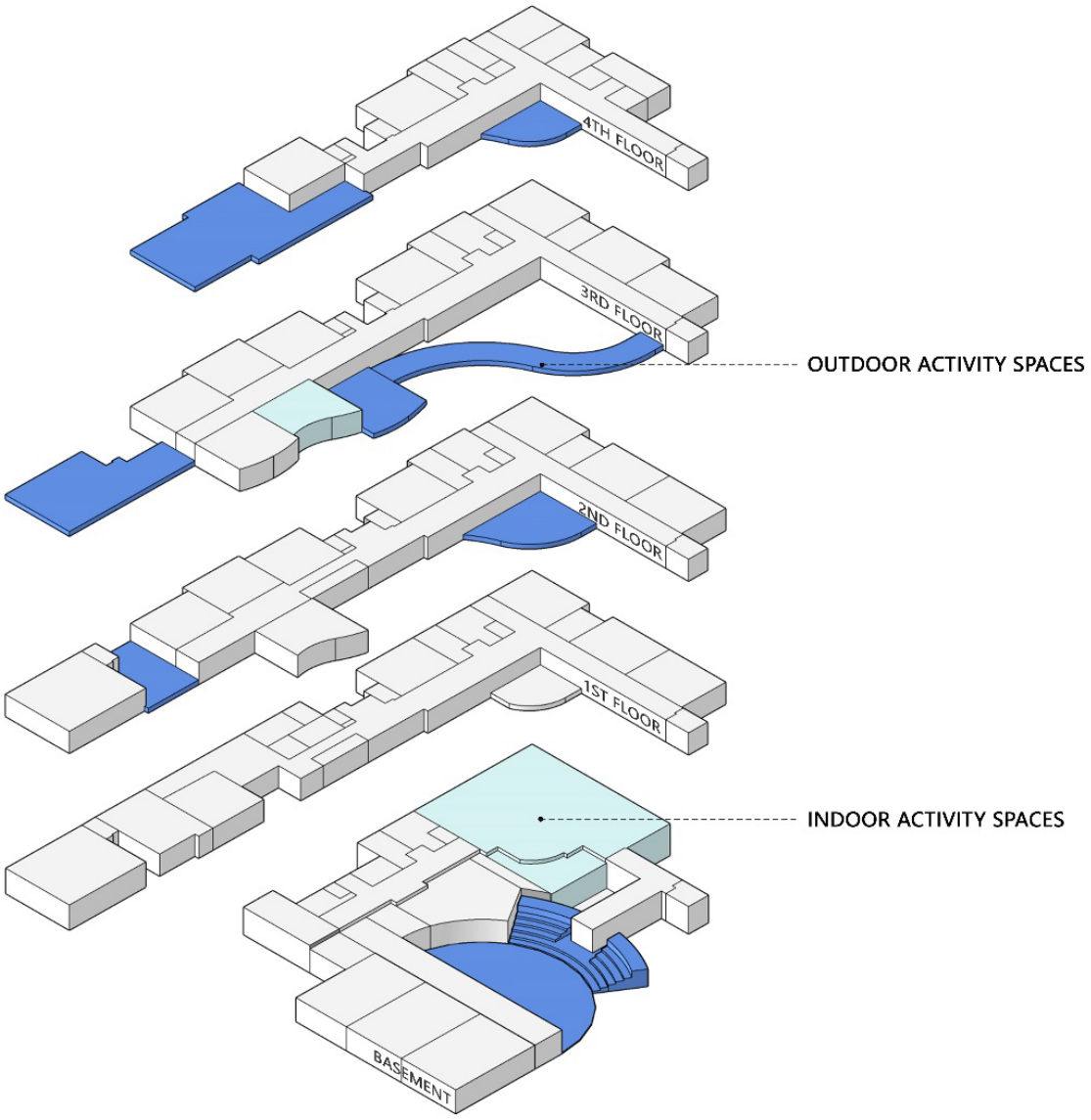

Figure 67: Activity spaces on each level

There are outdoor spaces on each floor so students on upper levels also have opportunities for physical activities. The different locations of the physical activity spaces are en route to other classrooms. This positioning influences students' subconscious to play outside when they see others playing. The indoor activity spaces are located in the basement and on the third floor, both of which can be used in mild and harsh weather.

	Existing(ft^2)	Proposed(ft^2)		Changes (%)
	Outdoor	Indoor	Outdoor	Total
Underground	N/A	4,665	2,809	N/A
First Floor/Ground	22,125	0	26, 493	20%
Second Floor	0	0	1,804	N/A
Third Floor	0	718	4,230	N/A
Fourth Floor	N/A	0	3,266	N/A
Total	**22,125**	**5,383**	**38,602**	**98%**

Table 7: Comparison of physical activity spaces

The proposed design improves the physical activity spaces overall. Each floor adds to the outdoor area, and the total physical activity space increases by 98%. Each student will have double the activity space compared with the current design.

4.2 Walking Distance

The walking distances from the classrooms to the outdoor spaces are evaluated below. The farthest classroom from the stairs and outdoor activity spaces on each floor is selected to measure the farthest distance and nearest distance and to compare them with the previous walking routes. The “Path of Travel” tool in Revit calculates the path length and time cost (at 3mph).

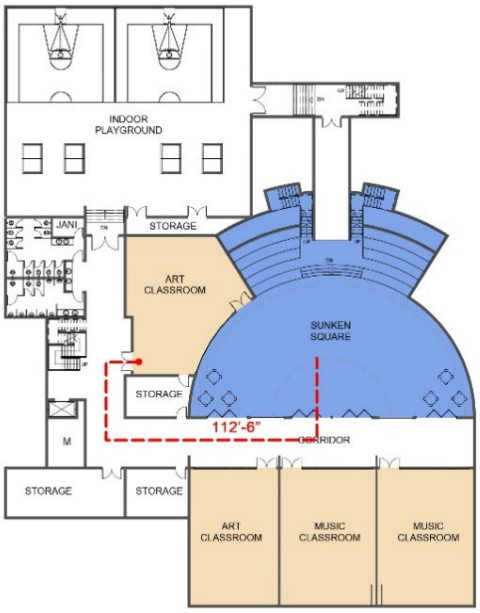

Figure 68: Basement walking path

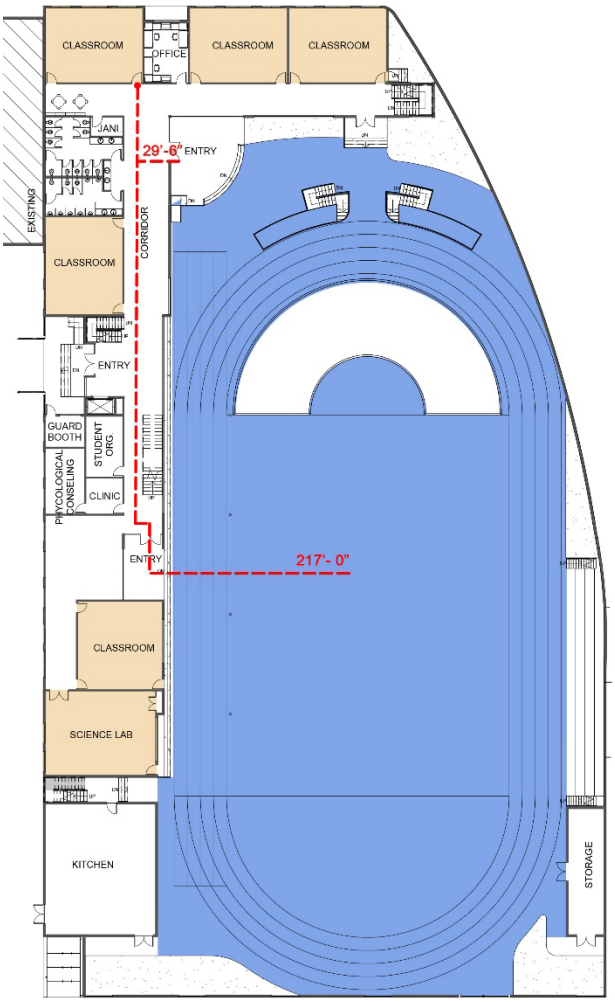

Figure 69: First-floor walking path

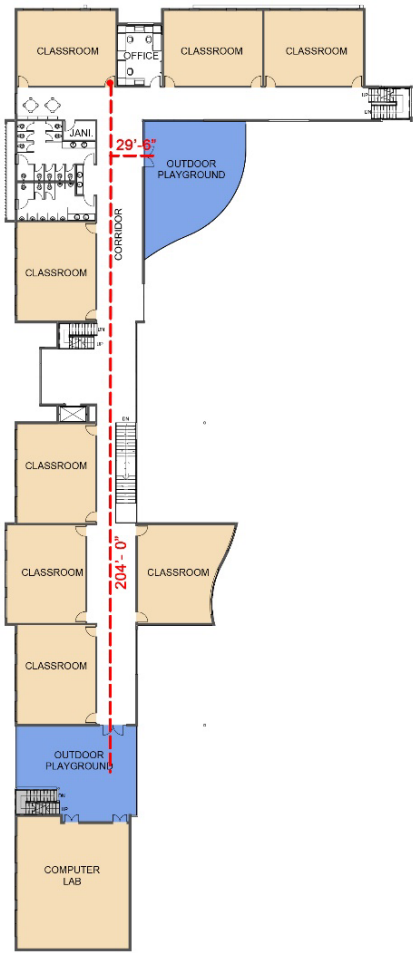

Figure 70: Second-floor walking path

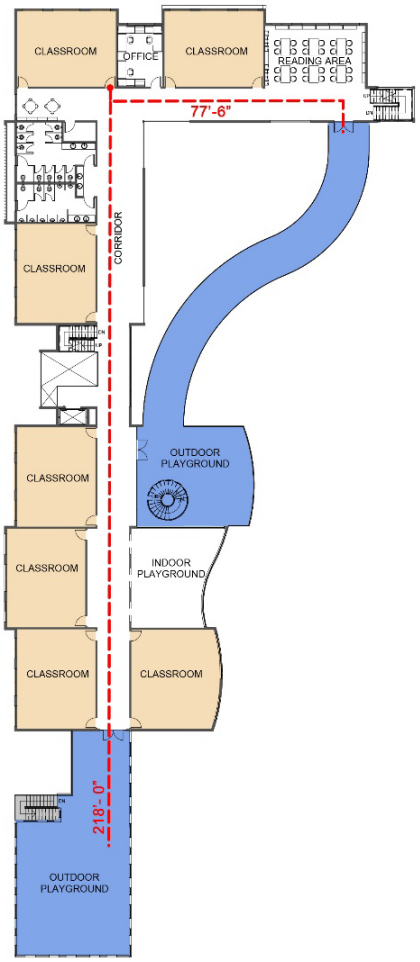

Figure 71: Third-floor walking path

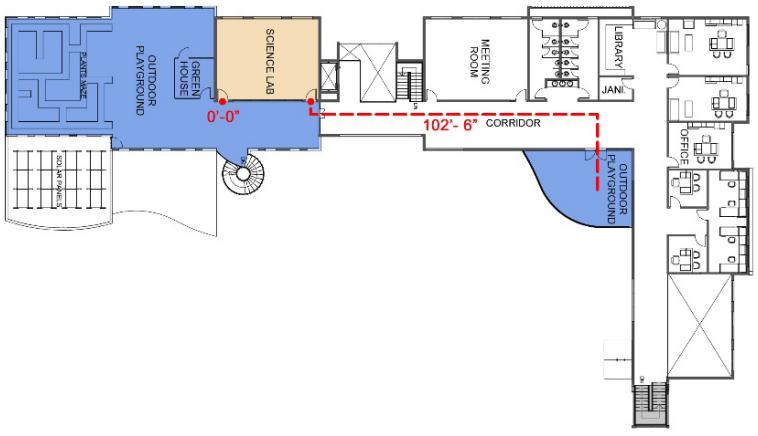

Figure 72: Fourth-floor walking path

	Existing		Proposed		Changes	
	Nearest	Farthest	Nearest	Farthest	Nearest	Farthest
Underground	N/A	N/A	N/A	112.5 ft	N/A	N/A
	N/A	N/A	N/A	25 s	N/A	N/A
Ground/first	141 ft	353 ft	29.5 ft	217 ft	-111.5 ft	-136 ft
Floor	32 s	80 s	7 s	49 s	-25 s	-31 s
Second Floor	191 ft	406 ft	29.5 ft	204 ft	-161.5 ft	-202 ft
	44 s	92 s	7 s	46s	-37 s	-46 s
Third Floor	244 ft	459 ft	77.5 ft	218 ft	-166.5 ft	-241 ft
	56 s	105 s	17 s	50 s	-39 s	-55s
Fourth Floor	N/A	N/A	0 ft	102.5 ft	N/A	N/A
	N/A	N/A	0 s	23 s	N/A	N/A
Average	192 ft	409 ft	34.1 ft	170.8 ft	**-226.1 ft**	**-238.2 ft**
	44 s	92 s	7.75 s	38.6 s	**-36.25 s**	**-53.4 s**

*Note: There is no outdoor area in the buildings in the existing design. The distance calculation for the existing design is from the classrooms to the ground-floor outdoor area.

Table 8: Comparison of walking distance and time cost from classrooms to same-floor outdoor areas

The average time is reduced by 36 seconds to the nearest outdoor area, and by 53 seconds to the farthest playground on the same floor. The return time is also reduced. A reduced distance to the outdoor playground promotes leaving classrooms. Students save time walking, which increases the time for play.

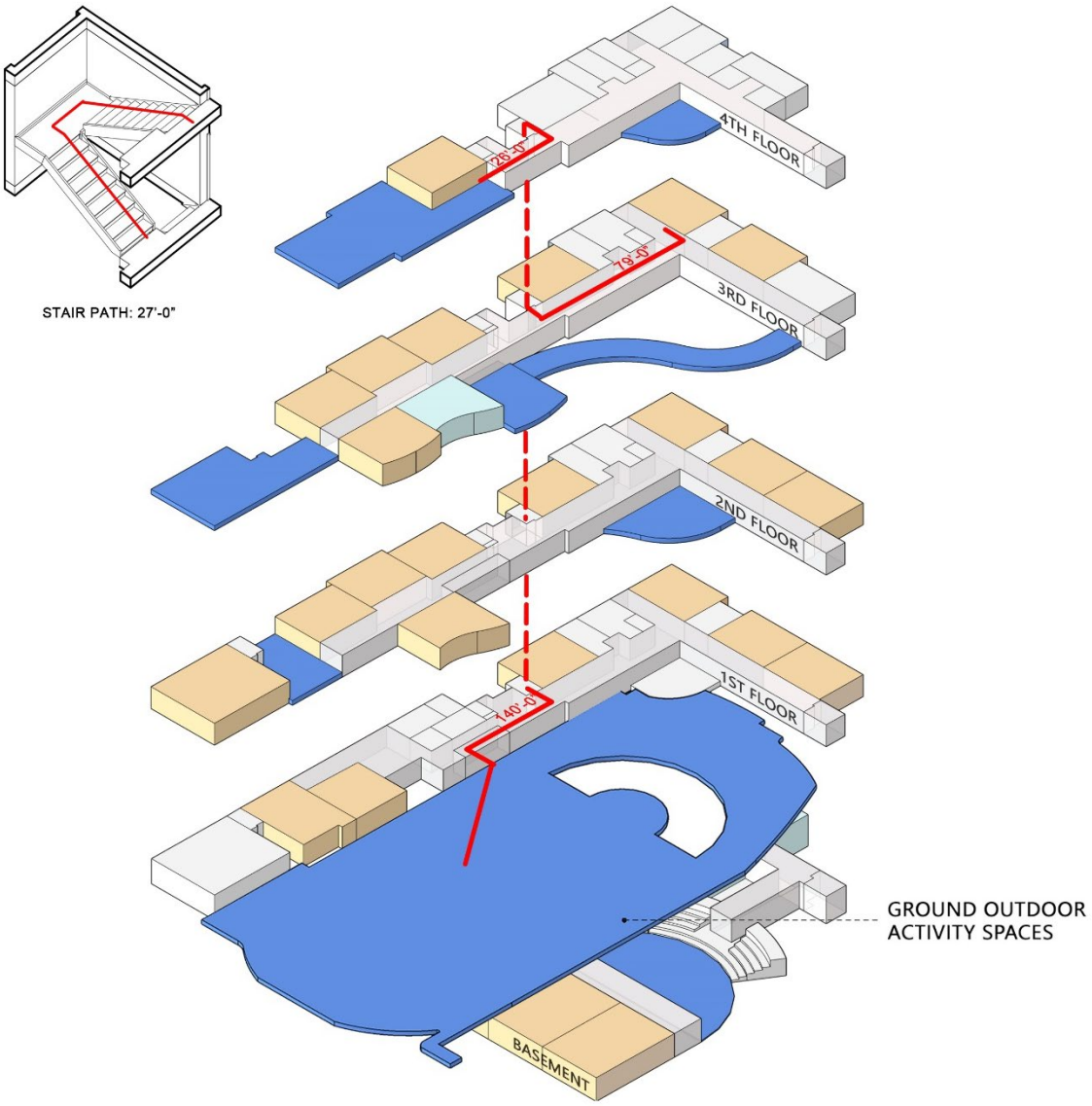

Figure 73: Farthest distance from classrooms to the ground

The ground has the largest outdoor space, allowing a large number of students to play here. The fourth-floor classroom is on the highest level of the building. The distance from this classroom to the center of the playground is 274 feet. The walking path from the farthest classroom on the third floor to the center of the playground is 297 feet (68 seconds). According to the existing design in Chapter 3, the longest distance is 459 feet (104 seconds). The proposed design shortens the walking distance from the classroom to the ground level

physical activity spaces. Students take less time walking to the largest playground. They can also access the outdoor spaces on the level above or below to play in different facilities.

4.3 Shading and Daylighting Analysis

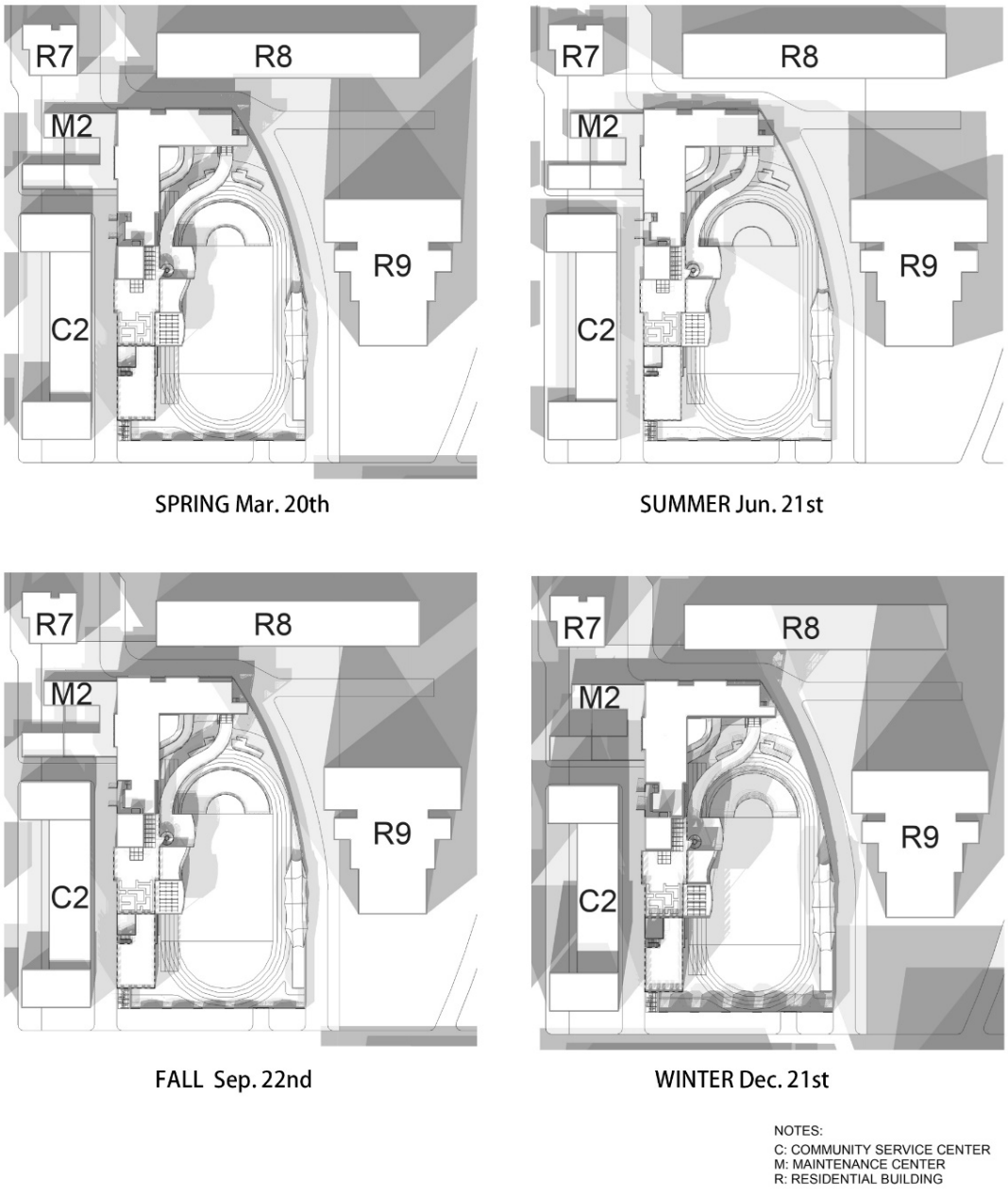

Figure 74: Shading analysis

Figure 74 illustrates the shading influences in the new design and the surrounding buildings. The students are on campus throughout spring and summer. The campus receives sufficient direct sunlight during these two seasons. In the summer, the north campus takes advantage of the shading from Building R9. In the winter, the school buildings affect most of the campus in terms of light, but the campus still receives enough direct sunlight during morning assembly physical activity recess. The large outdoor playgrounds on the third and fourth floors are always exposed to sunlight. Thus, there are multiple choices regarding exercise locations for students.

The proposed building is only four stories above ground, which impacts less on the surrounding buildings. The design occasionally shades a few lower levels of Building R8 in spring, fall, and winter. However, compared with Building R9, the effect is small.

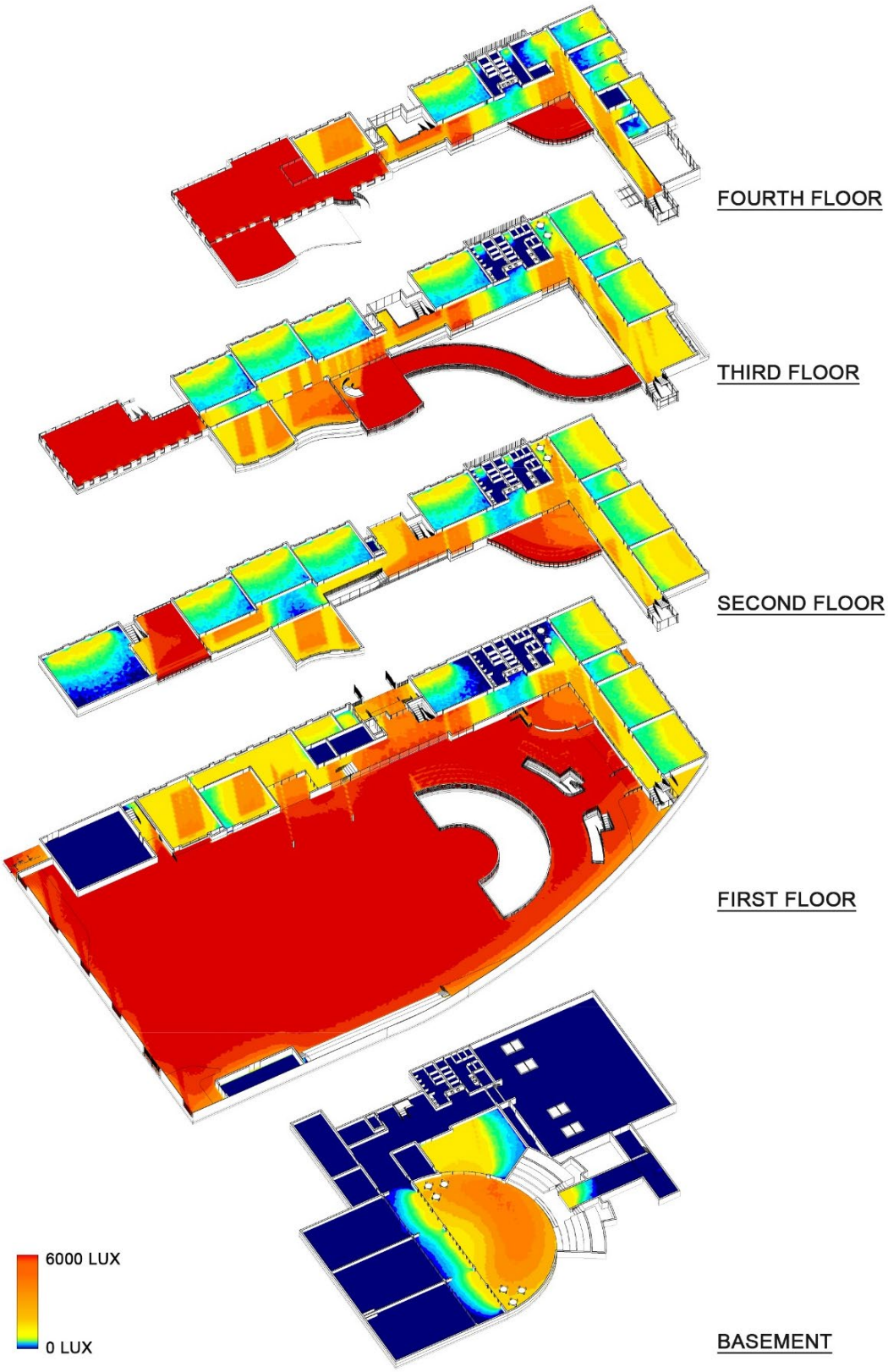

Figure 75: Daylighting Analysis

Figure 75 illustrates the daylighting analysis of the indoor and outdoor spaces. The outdoor areas all receive sufficient daylighting. The indoor area receives about 70% natural light, which is enough for regular activities, but it will require artificial lighting fixtures for better lighting levels for study. Most of the corridor areas are lit by natural light and do not require additional lighting sources in good weather. The basement receives the least amount of sunlight, but the spaces here are not always in use.

The building is outstanding in terms of the shading and daylighting performance of its outdoor physical activity spaces, achieving the goal of promoting student health. Moreover, improved shading and lighting performance increases the building's sustainability.

5. Conclusion

Physical activity is an essential part of children's lives. Students spend much of their weekday time in school, which is why schools' physical activity spaces are so important. The design proposed in this thesis improves the overall situation of an existing primary school.

1) The square footage of the total physical activity spaces is increased by 98%. Thus, each student has twice the amount of space to work out in compared with the existing design, with more opportunities to exercise and choices of different sports. Moreover, students have new areas for amusement that are not in the existing design.

2) There are different types of physical activity spaces on different levels. Some of these spaces are outdoor and exposed to sunshine; some are outdoors with cover; some are indoors, which could be useful when the weather is harsh; and some areas are partially indoor and partially outdoor. This variety allows students to engage in physical activity at any time. Compared with the existing design, which has only two outdoor areas on the ground, the new design improves the quality of the physical activity space.

3) The walking distances from the classrooms to outdoors or activity spaces are decreased significantly. The data reveal that the average path to the nearest outdoor space is about one-fifth the length of the existing nearest path, and the path from the farthest classroom to the ground-level play area is about three-fifths the length of the current farthest path. Thus, students will spend less time walking to go outside, saving an average of 1 minute to go to and return from the nearest outdoor area, 1 minute 46 seconds for the farthest

playground on the same floor, and 1 minute 12 seconds from the farthest classroom to the ground-floor physical activity space. These time savings enable children to play longer and encourage them to go outside.

4) Other space improvements. The size of the average classroom is increased by at least 124 square feet in the proposed design. The new design keeps the same number of existing classrooms and adds two art classrooms and two science labs to help children gain more knowledge. At the same time, each floor has a reading and relaxation area. Elevators and accessible facilities are added to the new design. Moreover, the overall spaces are enlarged to be more efficient.

5) Daylighting improvement. All the outdoor spaces will receive sufficient daylight and direct sunlight. The indoor areas will be mostly lit by natural light but will require artificial lighting fixtures for optimal performance.

In conclusion, this design successfully solves the issue of a lack of physical activity space in the dense city of Beijing. The proposed design promotes physical activity among children in the school. The design develops not only physical activity spaces, but also other basic functional spaces. It is a good prototype for future school designs. By coordinating with the educational system's improvements, students' physical and mental health are certain to improve.

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